Environmental Trends
in British Columbia: 2007

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Ministry of Environment

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Environmental Trends in British Columbia: 2007

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EXECUTIVE SUMMARY

This is the fourth in a series of Environmental Trends reports from the British Columbia Ministry of Environment. This year's report contains 44 indicators and over 25 supplementary measures divided into seven topics. The indicators were selected to provide an update on a wide range of measurable pressures and conditions in the province. They also show the impact of efforts to address environmental problems and the progress society as a whole is making toward sustainability.

The seven technical papers in this volume present background information on each topic, a set of indicators with supplementary information, and a summary of results. The data for each indicator are shown, together with a description of the methods of analysis and notes on interpreting the results. The papers also describe what is currently being done to address the issues by governments and other agencies, as well as what individuals can do about the issues.

Some of the core indicators in the 2007 report have been reported in earlier editions of Environmental Trends. Others, such as some of the species-at-risk indicators, are new, based on recent research. Selected indicators developed for the B.C. Coastal Environment: 2006 report (see *www.env.gov.bc.ca/soe/bcce/*) have been summarized and included to provide a comprehensive picture of the state of the provincial environment.

All results, including the full text of the papers and the data sets underlying the graphs, are also available to the public at *www.env.gov.bc.ca/soe/et07/*. The website provides accessible summaries of key information and links to other sites for further reference. A printed brochure describing the project and the overall results is also available.

SUMMARY OF KEY RESULTS

Population and Economic Activity

In 2007, over 4.6 million people lived in British Columbia. According to the most recent estimates, the B.C. population is expected to grow to 5.5 million people in 2030. As the number of people living in the province grows, pressure on the environment inevitably increases. Loss of natural habitat to development and agriculture, increasing demand for water, lumber, and other resources, release of pollutants, and production of waste all have environmental impacts.

- The most rapid growth rates in B.C. have taken place in Metro Vancouver, with the population density nearly doubling between 1976 and 2006. The Capital Regional District (Victoria) and the Nanaimo and Central Okanagan regional districts are the next fastest growing regions. Population patterns reflect both the continual expansion of urban centres and a shift in the economic and industrial activity within the province.
- In the Lower Mainland, policies at the regional level and provincial level (i.e., Agricultural Land Reserve) appear to have restrained suburban sprawl and slowed the loss of rural land.

Between 1991 and 2001, the population of the region increased by 25%, yet the area of land converted to urban uses increased by only about 2%.

- The Agricultural Land Reserve (ALR) was put in place at the provincial level to protect agricultural land in 1974. Since then the total area, province-wide, has increased slightly (1%). Most of the movement of land in and out of the ALR has been "secondary capability land," meaning that the land is suitable mainly for grazing or growing forage crops.
- As the level of sewage treatment increases, fewer contaminants are released into the environment. The proportion of the B.C. population with primary sewage treatment (35%), secondary treatment (56%), and tertiary treatment (8%) has remained the same since 1999.
- Recycling and waste diversion programs have succeeded in keeping the total amount of disposed waste in B.C. today to about the same total volume as in 1990, despite the increasing population. The amount of waste disposed per person is still lower than it was in 1990, but there has been little change in the last decade.
- British Columbia has eight industry-led product stewardship programs. Seven established programs cover used oil, scrap tires, lead-acid batteries, beverage containers, medications, tree-marking and household paint, solvents, and pesticides. To complement these programs the new Electronic Products Waste Program was put in place in 2007. Records from these established programs show that a large volume of hazardous and non-biodegradable products has been successfully diverted from landfills.
- Since 1981, the energy intensity for economic activity in B.C. has decreased. This equates to a lower environmental impact per unit of economic activity (GDP or gross domestic product), because it takes less energy to accomplish the same activity.

Air Quality

Airborne particulate matter and ground-level ozone are the two main air pollutants found in smog. They are of concern because even low levels of exposure may pose a health risk. Once in the lungs, fine particulate matter contributes to bronchitis, aggravates asthma and cardiovascular disease, and causes other lung-related problems. Exposure to ground-level ozone causes similar problems.

In 2000, the Canadian Council of Ministers of the Environment endorsed Canada-wide Standards (CWS) for ground-level ozone and fine particulate matter. These standards set targets for concentrations of both air pollutants to be achieved by the year 2010. B.C. now uses CWS to measure achievement of objectives to improve air quality.

- All communities with continuous air monitoring in B.C. had levels below the CWS target for particulate matter smaller than 2.5 micrometres in diameter (called $PM_{2.5}$). Only the levels in Prince George – the highest in the province – approached the target.
- Most communities in B.C. had levels below the CWS for ground-level ozone. The CWS for ozone was exceeded at Hope for the past 3 years, whereas readings at Chilliwack, Langley Central, and Maple Ridge were at or near the CWS threshold.

- For other air pollutants, monitoring showed that levels of nitrogen dioxide in all communities were below the Canadian objective. Levels of sulphur dioxide in all communities except Trail met the B.C. annual objective.

Fresh Water

British Columbia has an abundance of water compared to other parts of the world. However, fresh water supplies in some parts of the province are under pressure from increasing population and economic activity, showing the importance of careful stewardship of water resources.

- In 2006, 51% of the surface water sites monitored had a Water Quality Index rating of "good" or "excellent," 39% were "fair," 10% were "marginal," and none were rated as "poor."
- Results from long-term surface fresh water monitoring show that water quality improved at 34% of sites, remained stable at 56% of sites, and deteriorated in 10% of sites.
- Between 2000 and 2006, about 35% of the wells used to monitor ground water levels showed declining water levels, mainly due to local pumping for industry, agriculture, or drinking water.
- Out of 815 aquifers that have been mapped in B.C., 64 are rated as heavily developed. Most of these are on Vancouver Island, the Gulf Islands, and in the Southern Interior, where ground water withdrawal and urban development has been intensive.
- Of the mapped aquifers, 28 are rated as highly vulnerable to contamination and 53 have documented quality concerns such as salty water, nitrates, and arsenic.
- Residential use of municipal water decreased slightly from 465 litres per person per day in 1991 to 425 litres in 2004. This is still above the Canadian average of 329 litres per person per day, putting B.C. in the top bracket of water consuming provinces.

Climate Change

As greenhouse gas concentrations in the atmosphere increase, global temperatures are also rising because more energy from the sun is being trapped by the atmosphere. Records show that global temperatures, averaged world-wide over the land and sea, have been rising. British Columbia is experiencing a pattern of warming consistent with broader North American and global trends.

Since 1950, average temperatures have increased at most recording stations in the province. The greatest increase was recorded in the northern and interior regions, with average increases of 0.3 to 0.5°C per decade at most locations. Overall, the overnight minimum air temperatures in the province have been increasing faster than the daytime maximums.

- Climate models project a continuing warming pattern, with average temperature increases of 2 to 4°C throughout the province by 2050.

- Sea surface water has become warmer all along the B.C. coast over the last 50 years, with increases of up to 0.9°C in water temperature at the warmest locations. Deep water in inlets also shows a warming trend of 0.5 to 1.0°C over the past 50 years.
- Precipitation patterns over the last 50 years show that winters throughout most of the province have been drier, while spring and summer seasons have been wetter. Climate model projections for mid-century suggest different patterns of precipitation in the future: the northeastern areas may become wetter and the southern interior may become marginally drier in the winter. The southern and coast regions are both projected to become drier in the summer.
- An analysis of snowpack records shows that the greatest average decrease in snowpack has been in the mid-Fraser River system, while snowpack has increased in some northern sites. Rivers in the north and interior of the province, especially at lower elevations, swell earlier in the year; several now reach peak flow more than 15 days earlier.
- Relative sea level has risen at Prince Rupert, Vancouver, and Victoria over the last 50 years. Low-lying areas at greatest risk from rising sea levels include the Fraser Delta and the Naikoon area of the Queen Charlotte Islands.
- Total greenhouse gas emissions in B.C. rose about 30% between 1990 and 2004, in line with increasing population. In 2005, emissions were slightly lower than in 2004. However, greenhouse gas emissions per person have remained about the same since the 1990s.
- Since 2002, B.C. drivers, have been driving fewer kilometres each year and sales of smaller passenger cars have been increasing relative to sales of larger vehicles such as light trucks and SUVs.

Contaminants

Over 23,000 chemicals are in use in Canada. Most of the indicators pertain to persistent organic pollutants (POPs), most of which are industrial chemicals or byproducts of incineration; some were used as insecticides. POPs have a variety of toxic effects and most persist for a very long time in the environment, becoming more concentrated in the bodies of animals higher up the food chain.

- Total on-site releases and disposal of toxic substances in B.C. remained about the same for 2002–2005. Pollutants released in the largest quantity include hydrogen sulphide, sulphur dioxide, ammonia, and methanol.
- Since 1990, the levels of dioxins (byproducts of pulp bleaching processes) in pulp and paper mill effluent have dropped to undetectable levels. Levels in sediments and in crabs living near mill outfalls have also declined steeply. The results are correlated with changes in regulations and pulp mill technology that were made to address the issue.
- British Columbia is making progress cleaning up contaminated sites. As of 2006, 71% of the approximately 6,800 contaminated sites registered in the provincial database have been remediated or are in some stage of the process.

- Monitoring for POPs in bird eggs in B.C. shows that concentrations of PCBs, dioxins, furans, and organochlorine pesticides have decreased over the last 30 years. At the same time, there has been a rapid increase in concentrations of PBDEs, which are flame retardant chemicals widely used in consumer goods.
- Research on POPs in marine mammals on the B.C. coast shows that tissues of killer whales are contaminated with PCBs and PBDEs. Contaminants in the tissues of harbour seals differ regionally: Puget Sound seals have the highest concentrations, whereas Queen Charlotte Sound seals are the least contaminated.
- Efforts to reduce pesticide use in landscapes have led to a 50% reduction in the quantity of pesticide used by landscape services in the lower mainland of B.C. since 1991. By 2004, four of the six landscape pesticides of most concern in the Georgia Basin in 1991 were no longer in use.

Ecosystems

Healthy ecosystems provide essential "services" that people rely on: clean water and air, food and fibre production, waste treatment, climate regulation, protection from flooding and erosion, and many other functions. Human activities have degraded, fragmented, and even eliminated some ecosystems in B.C., making it more important than ever to establish protected areas and manage development activities.

- Grasslands are Canada's most endangered ecosystem. About 16% of original southern interior B.C. grassland has been lost, mostly before 1990. Only about 8% of the remaining grasslands in the area are now protected.
- Forests in B.C. cover 65% of the area of the province (33% is naturally non-forested); 2% of the land base has been permanently converted to non-forestry uses, mainly due to the expansion of urban areas.
- Estuaries are essential ecosystems, home to most coastal wildlife, including salmon and migratory birds. About 38% of 440 mapped estuaries in B.C. have economic tenures and 28% have conservation tenures.
- The total protected area of B.C. has more than doubled since 1991. Legally designated protected areas cover 13.4% of the provincial land base; another 0.6% of the province has been identified for legal protection.
- Although ecosystems within the province are not equally represented within the system of protected areas, they are better represented now than they were in 1991. About a third of terrestrial ecosections have over 12% of the area protected (doubled since 1991). Marine ecosections are the least represented, with most having less than 5% of their area protected.
- The total area of protected forest has more than doubled since 1991 and now covers 9.7% of B.C. forests. The protected area of both low and high elevation forests has also increased.
- About 8% of the province is both protected and ecologically intact (i.e., without roads). The central and north coast and the northwest have the largest tracts of intact land; therefore, protected areas in these regions are mostly surrounded by intact landscapes.

- Protected areas in the southern interior and south coast are surrounded by landscapes fragmented by roads; in northeastern B.C., the landscape is fragmented by seismic lines.
- Between 1988 and 2005, the total length of roads in B.C. increased by 82%. The Georgia Depression ecoprovince (which includes Vancouver) has the most roads per square kilometre.

Species Conservation

The varied geography of British Columbia, ranging from coastal islands to rain forests, mountains, and the grasslands of the interior, makes the province one of the most biologically diverse areas in Canada. Some species are found nowhere else in Canada and over 162 species of birds breed only in B.C. Many B.C. species have been designated as endangered, threatened, or of special concern because there is a risk they may become extinct, at least locally.

- In 2007, the B.C. Conservation Data Centre listed 490 species on the provincial red list of species most at risk.
- Since 1992, the number of species of mammals and freshwater fishes with deteriorating conservation status outnumbered the species with "improving" status. The number of breeding bird species with "improving" status roughly equalled those deemed to be "deteriorating."
- Since 1996, the number of plant species on the provincial red list rated as "deteriorating" in status outnumbered those with "improving" status.
- Although there are more red-listed plants than animals, the groups with the greatest proportion of red-listed species are freshwater fishes (37%) and reptiles and turtles (41%).
- Recovery strategies are now in place or in development for 95% of species at risk in B.C. Strategies for 26% of species or species groups have been approved and published.
- The greatest threat to most (86%) species currently listed at risk is loss of habitat due to human activities. The second greatest threat is impact from non-native species.
- In 2007, 809 non-native species were recorded in B.C. These species have been accidentally or intentionally brought into the province in agricultural products, through landscape nurseries, or by other human activities.

Plants comprise the largest group of known non-native species in B.C., with numbers increasing by 29% since 1994. As of 2005, 860 waterbodies in B.C. were known to be inhabited by at least one non-native species of freshwater fishes.

Population and Economic Activities

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Population and Economic Activities

BACKGOUND

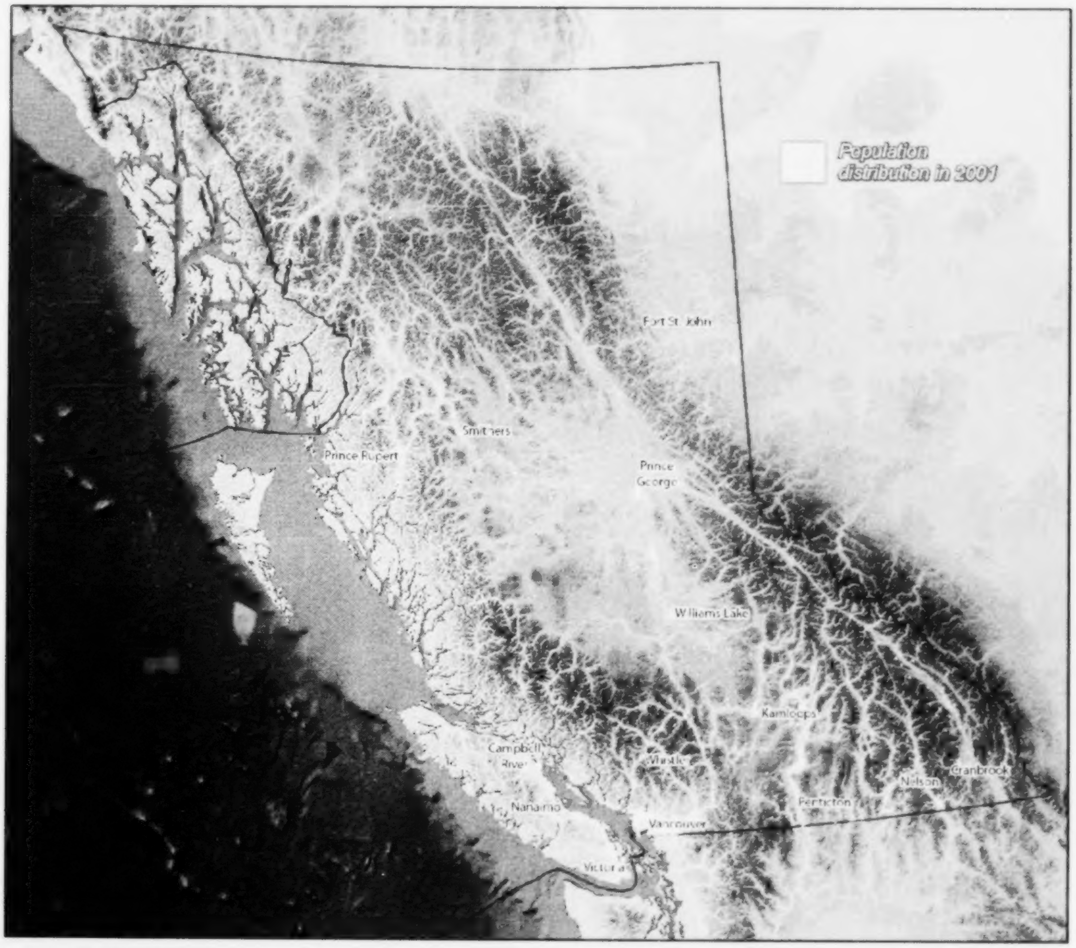
The Growing Provincial Population

Estimates of the pre-European population of British Columbia range from 60,000 to 200,000 (Glavin 1996; Harris 1997). Diseases brought by Spanish and British explorers decimated the Aboriginal populations of B.C. and by the middle of the 19th century their numbers had dropped to a fraction of their former size. As the Aboriginal population declined, European settlement along the coast continued to grow. In 1851 the population of B.C. as a whole was 55,000; in 1951 it was more than one million, and by 2006 it was over 4.3 million (Statistics Canada 2005; BC Stats 2006). By 2001, most (76%) of the province's population, or just over 3 million people, lived in the coast regions, mainly in the Lower Mainland and southern and eastern parts of Vancouver Island (Figure 1). In 2001, the Aboriginal population was 170,025 and accounted for 4.4% of the total B.C. population.

The provincial population has been growing faster than Canada as a whole: from 1996 to 2001, B.C.'s population increased by 4.9%, while Canada's population increased by 4.0% (BC Stats 2003). From 2004 to 2005, B.C.'s population grew by 1.3% (BC Stats 2006).

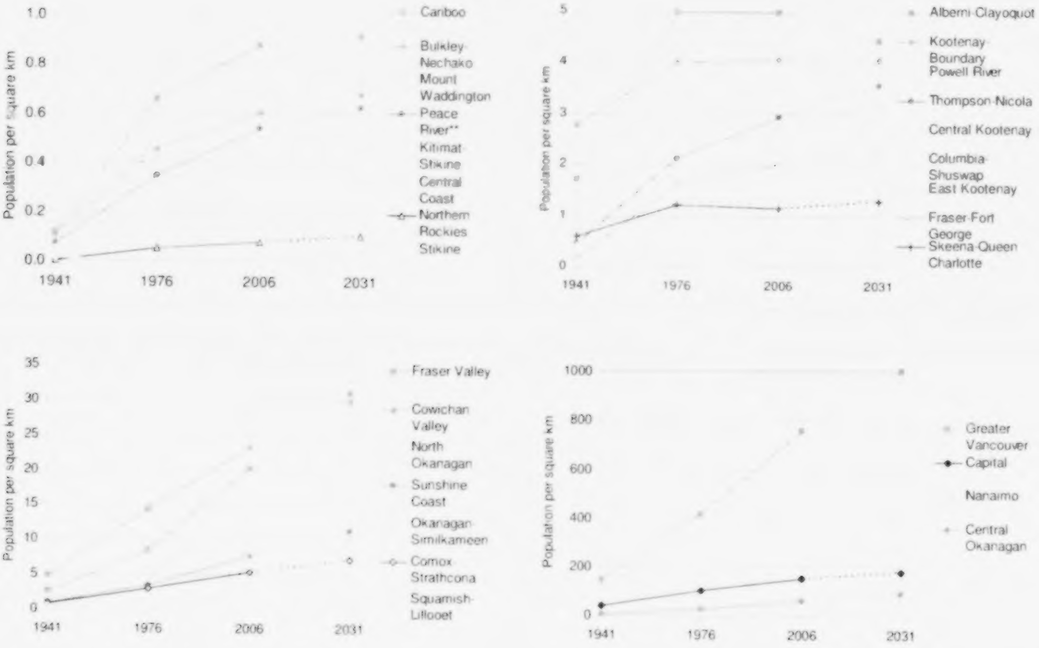
As the number of people living in the province increases, pressure on the environment inevitably will increase, whether through land use changes, increasing water demand, waste production, or emissions of pollutants. Population density projections, calculated as the number of people per square kilometre, show where the greatest pressures on land and marine areas are likely to be. Patterns of change in population density in regional districts, along with projected density in 2025, are shown in Figure 2 and Table 1. The four graphs have different scales on the vertical axis to account for the great difference in relative size of the districts.

Figure 1. Population distribution in B.C., 2001 (one dot equals 50 persons).


Population distribution in 2001
Fort St. John
Smithers
Prince Rupert
Prince George
Williams Lake
Kamloops
Whistler
Campbell River
Nanaimo
Vancouver
Victoria
Penticton
Nelson
Cranbrook

Source: BC Stats 2004.

Figure 2. Population density (people/km^2) in the regional districts of B.C. for 1941, 1976, and 2006, and projected for 2031. Note the different scales on the graphs.



Sources: 1941 population figures from the census as published by Statistics Canada with adjustments to align with current boundaries; figures for 1976 and 2006 from the most current BC Stats estimates (Dec. 2006); 1976 data from internal documents at BC Stats; projections for 2031 from the PEOPLE 31 projection run, which is benchmarked to 2005 population estimates.

Table 1. Population density in the regional districts of B.C. for 1941, 1976, and 2006, and projected for 2031.

	Population density (people/km^2)			
Regional district	1941	1976	2006	2031
Stikine	0.01	0.01	0.01	0.01
Northern Rockies	nd	0.05	0.08	0.10
Central Coast	0.15	0.16	0.16	0.16
Kitimat-Stikine	0.09	0.43	0.47	0.53
Peace River**	0.07	0.35	0.54	0.62
Mount Waddington	0.28	0.63	0.67	0.65
Bulkley-Nechako	0.11	0.46	0.60	0.68
Cariboo	0.11	0.66	0.88	0.92
Skeena-Queen Charlotte	0.58	1.21	1.15	1.29
Fraser-Fort George	0.15	1.60	1.99	2.18
East Kootenay	0.68	1.73	2.29	2.29
Columbia-Shuswap	0.40	1.27	1.88	2.31
Central Kootenay	1.24	2.27	2.74	3.17
Thompson-Nicola	0.45	2.13	2.94	3.55
Powell River	1.59	3.92	4.20	3.91
Kootenay-Boundary	2.78	4.01	4.06	4.06
Squamish-Lillooet	0.44	0.99	2.31	4.25
Alberni-Clayoquot	1.70	4.97	4.99	4.44
Comox-Strathcona	0.81	2.93	5.36	7.13
Okanagan-Similkameen	1.77	5.06	8.15	10.40
Sunshine Coast	0.94	3.40	7.75	11.18
North Okanagan	1.99	6.39	10.90	14.51
Cowichan Valley	4.85	14.34	23.12	29.69
Fraser Valley	2.46	8.45	20.15	30.81
Central Okanagan	4.34	25.11	59.58	87.57
Nanaimo	8.00	30.44	70.66	101.77
Capital	36.94	100.91	151.09	178.94
Greater Vancouver	142.18	417.40	757.59	1004.72
B.C. total	0.88	2.73	4.65	6.06

Sources: 1941 population figures from census as published by Statistics Canada, adjusted to align with current boundaries; 1976 and 2006 figures from the most current BC Stats estimates (Dec. 2006); 1976 data from BC Stats internal documents; 2031 projections from PEOPLE 31 projection run, which is benchmarked to 2005 population estimates.

Notes: Peace River includes Northern Rockies in 1941. Regional District names are those used in 2006; those in bold have been adjusted to conform to 2006 categories.

The most rapid growth rates have occurred in the largest metropolitan area of Vancouver. Not surprisingly, Metro Vancouver (formerly the Greater Vancouver Regional District) also has the greatest population density. In the 30 years between 1976 and 2006, the population nearly doubled and the population density is projected to continue increasing. The Capital Regional District (Victoria), and the Nanaimo and Central Okanagan regional districts are the next fastest growing areas. They are all projected to continue increasing, but at a markedly slower rate than Metro Vancouver. The Fraser Valley and Cowichan Valley, are also fast-growing areas. Population density is increasing markedly in the North Okanagan, Sunshine Coast, Okanagan-Similkameen, Comox-Strathcona, and Squamish-Lillooet regional districts. The increase in the latter area is due mainly to the recent rapid growth around Whistler.

Although the provincial population continues to rise, and density is increasing in the southern parts of the province, the populations of some regional districts have not grown. In Skeena-Queen Charlotte, density actually decreased somewhat between 1976 and 2006, probably because of the downturn in the forest industry in these communities. The 2031 projections show that population density for Alberni-Clayoquot, Powell River, Mount Waddington, and East Kootenay may drop slightly.

The population patterns reflect both the continual expansion of urban centres and a shift in the economic and industrial activity within the province. Population declines in rural and remote areas are associated with the decline in relative importance of traditional labour-intensive resource industries such as forestry and fisheries.

Impacts of a Growing Population on the Provincial Environment

Most state of the environment indicators, including those in this report, show the impacts of increasing provincial, national, and global populations. According to the most recent population estimates, the total B.C. population is expected to exceed 5.5 million by 2030 (BC Stats 2007b). The most visible impact on the environment from the growing population is the permanent loss of habitat to industrial and residential development in the areas with the highest populations. Forested land, grasslands, wetlands, estuaries, and the riparian zones along streams, lakes, and seashores have all been disturbed or lost to provide housing, employment, recreation, and transportation for people. Increasing use of urban and suburban land brings expanding transportation and utility corridors to move goods and people between urban centres and suburbs. As development spreads out or "sprawls" in an unplanned manner beyond existing urban centres, it encroaches on natural habitats and agricultural lands. Urban sprawl also means that people travel farther from homes to work or shopping areas, leading to heavier reliance on roads and cars. As natural land cover, which has a greater capacity to filter water from rainfall and snowmelt, is replaced by pavement and other impervious surfaces such as buildings, precipitation that should percolate into the soil is rapidly carried away into storm sewers. This means that the rain water is not available to recharge underground aquifers or replenish natural watercourses.

Another consequence of increasing population and density is increasing air and water pollution and release of other contaminants from human activities. Both fresh and marine water quality are affected by the release of excess nutrients and contaminants into the environment from sewage, agricultural and surface runoff, and vehicle and marine vessel traffic. The growing scale of sewage and solid waste disposal problems, as well as release of smog-forming chemicals and greenhouse gases, strains both local and global ecosystems.

Concern about the negative environmental and social impacts of urban and suburban sprawl has given rise to "smart growth" approaches to land-use planning and development. Smart growth is defined as land use and development practices that enhance the quality of life in communities, preserve the natural environment, and also save money over time (Curran and Leung 2000). Local governments are applying smart growth principles to regional growth strategies and official community plans. Smart growth strategies have been found to increase the liveability and economic vitality of developed areas, especially in larger municipalities (Smart Growth BC 2004).

Paradoxically, declining populations in rural and remote communities also create pressure on the surrounding environment. Many communities are struggling with the loss of natural resource industries (e.g., logging, fishing) and are working toward diversifying their economy. The issues facing these communities in transition include job loss, shrinking tax base, school closures, loss of health services, deteriorating infrastructure, and less government funding.

INDICATORS

The indicators in this paper show selected pressures on B.C.'s environment from population growth, distribution, and density, and from human activities, as well as responses that address those pressures.

The indicators fall into three general categories: patterns of use on land and sea, liquid and solid waste management, and economy and the environment. The latter category reflects the fact that the economy is a strong driving force for both positive and negative change in the environment. Gross domestic product (GDP) measures the total value of goods and services produced in Canada. This includes goods-producing industries (such as manufacturing, construction, and resource extraction enterprises) and service-producing industries (such as wholesale and retail trade and health care).

Patterns of Use on Land and Sea

1. Key Indicator: Rate of change of selected land uses in Metro Vancouver, 1986 to 2002

This is an impact indicator. It was developed as one of several indicators addressing the impact of increasing population on the coast; it specifically reports on land use changes and impacts of "smart growth" strategies in the Vancouver area.

Changes in land use patterns show the pressures that expanding human population and economic activities are placing on the surrounding environment. Tracking the rate of change over time can help determine whether efforts to limit urban sprawl are effective. This indicator reports the results of an analysis of land use changes in Metro Vancouver (formerly the Greater Vancouver Regional District or GVRD) between 1986 and 2002 (BCMSRM 2004). The results were reported in the B.C. Coastal Environment: 2006 report (BCMOE 2006a) and are summarized in this paper. (For the full report, see *www.env.gov.bc.ca/soe/bcce/01_population_economic/landuse_changes.html*.)

Methodology and Data

In 2004/05, a pilot project was undertaken to map changes in land-use patterns in Metro Vancouver using satellite imagery. The project was funded jointly by the provincial government, the Biodiversity Conservation Strategy for the Greater Vancouver Region initiative, Environment Canada, and Natural Resources Canada. It was managed by the Business Solutions Branch of the B.C. Ministry of Sustainable Resource Management (now the Integrated Land Management Bureau, Ministry of Agriculture and Lands).

This study examined changes over time in the characteristics of land use at a broad or regional level, as reflected in land cover visible in satellite imagery. The type of land cover (composition and characteristics of land surface) is a result of a mixture of natural and human influences. Land use, however, is characterized by the economic uses of land and people's relationships with the environment. This means that determining land use change from satellite photographs, which show land cover, is complex and requires cross-referencing with other data sources.

The study area covered a total of 375,456 ha, consisting of the Metro Vancouver area plus a 2-km buffer (except along the US border) and only areas above the high water mark.

Land-use maps at an overview level and land-use change maps were produced for four time points (1986, 1993, 1998, and 2002) primarily from Landsat satellite imagery. Other sources of information, including existing maps, digital orthophotographs, air photographs, and supplementary inventory datasets, were used to complete the maps.

Results for all years are shown in Table 2 and Figure 3, which shows the net change in each category, for each period, and for the entire study (1986 to 2002).

Table 2. Change in land use in Metro Vancouver (GVRD), 1986 to 2002, and net change for the entire study period.

	Land use (ha)							
	1986	1993	Change 1986-1993	1998	Change 1993-1998	2002	Change 1998-2002	Net change[a] 1986-2002
Agriculture/urban mix[b]	16,511	16,511	0	17,430	919	17,393	–37	+882
Agriculture	31,728	31,684	–44	31,712	28	31,733	21	–7
Forest								–2996[c]
Old (≥140 yrs)	70,245	68,691	–1555	68,459	–231	68,436	–23	
Young (<140 yrs)	66,634	66,627	–6	66,772	145	67,399	627	
Recently logged	7,499	8,760	1261	6,530	–2230	5,806	–724	
Selective logged	559	559	0	0	–559	0	0	
Mines (gravel pits)	2,009	2,077	68	2,139	63	2,132	–7	+124
Recreation	707	707	0	1,182	475	1,178	–4	+479
Urban	93,660	93,936	276	95,761	1826	95,910	149	+2251

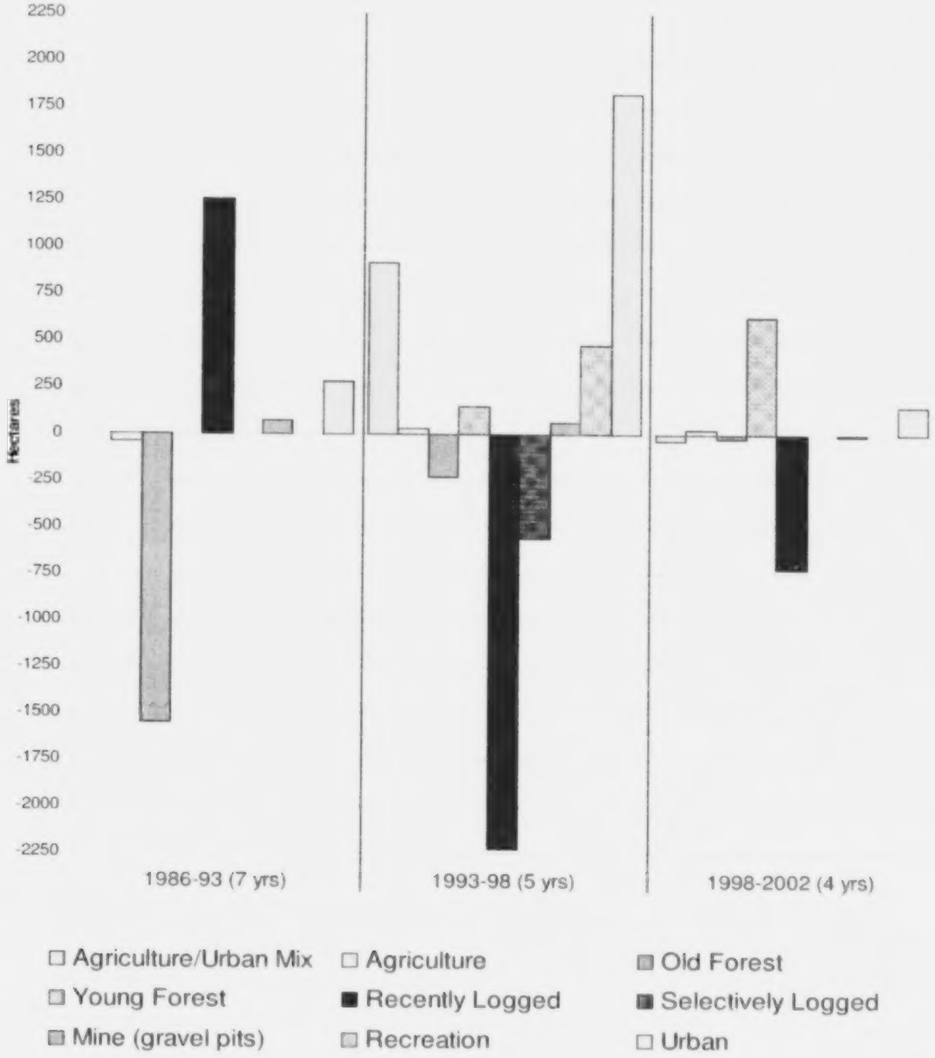
Source: BCMSRM 2004.

[a] Net change is the sum of positive and negative changes in area, thus does not show whether a particular use may have gained area in one location while losing it in another location.

[b] Due to the relatively coarse mapping level, small changes, such as in density of housing, may not be detectable in this category.

[c] Figures for the four forest classes were combined to calculate the total net change in forestry land use. This takes into account the fact that some areas moved from "recently logged" to "young forest" (<140 yrs) and others moved from young to old forest (≥140 yrs) over the 16-year period.

Figure 3. Net change in land use (ha) in Metro Vancouver (GVRD), 1986–2003, by land cover and land use type.



Source: BCMSRM 2004.

Most of the land use changes between 1986 and 2002 actually occurred in the 1993 to 1998 period. During this period, a rapid rate of urbanization of the region is shown by the higher rate of change to more urbanized land uses in this time. A more detailed analysis of the land use conversions showed net losses of forests and agricultural land, mostly to urbanization. The urban land use category grew by 1826 ha. During 1993–1998, 2332 ha of young forest were converted to other uses, most (1,721 ha) to urban or mixed agriculture/urban use. This conversion is not evident from the net change figures for the period because it is masked by a large area that moved from "recently logged" to "young forest."

All selectively logged lands recorded in 1986 were converted to mixed agricultural/urban land use by 1998. The agriculture/urban mix category increased by 919 ha (an increase of more than 5%), compared to no change in area during the previous period.

Another related land use change brought about by increasing population and consumer demand was the conversion of lands outside of urban use areas (agriculture and young forest) to recreational uses such as ski areas, golf courses, and large waterfront cottage areas. Recreational-use land increased by 67% (475 ha).

After 1998 the rate of conversion to urban use fell to one-tenth of the previous five years, with some of the new urban hectares coming from agriculture/urban mixed use land (i.e., from already urbanizing areas), and from young forest lands. The largest net change was a total of 850 ha that was re-established as young forest after appearing in the previous period as "recently logged."

Interpretation

Overall, land use change accelerated during the 1993 to 1998 period, after which the rate of change slowed considerably. These statistics show that most of the expanded urban area came from forest land (1113 ha), with conversion of agricultural land second (373 ha). Although the percentage increase in urban use area (about 2%) since 1986, and in agriculture/urban mix use area (about 5%), may seem small compared to the size of the region, these changes took place over a relatively short period.

Given the continued increase in population—more than 25% during a similar time period (1991–2001) for Metro Vancouver (BC Stats 2004)—these trends appear to confirm the success of urban containment or smart growth strategies within the Greater Vancouver Regional District. A 2002 study by Northwest Environment Watch and Smart Growth BC compared urban sprawl for Greater Vancouver (including most municipalities in Metro Vancouver) and Greater Seattle and reported that, despite a very high growth rate, Vancouver's policies had resulted in 62% of its population living in compact communities (30 persons per ha or more) in 2001 (Northwest Environment Watch 2002). Five years earlier, 57% of the Vancouver population lived in compact communities. In comparison, 25% of Seattle residents lived in compact communities in 2000. This means that Seattle residents take up more land per capita, with greater impacts on the regional environment, than Vancouver residents.

In the Lower Mainland, policies at the regional level, such as the Greater Vancouver Regional District's Liveable Region Strategic Plan, coupled with municipal land-use policies and the provincial Agricultural Land Reserve (ALR), appear to have restrained suburban sprawl and slowed the loss of rural land and open space over the last 30 years (Northwest Environment Watch 2002). Population and density, however, continue to increase on the B.C. coast, particularly in the areas north and east of Metro Vancouver (BC Stats 2004).

2. Key Indicator: Changes in area of the Agricultural Land Reserve in B.C. since 1974

This is a pressure indicator showing the change in area and quality of land in the Agricultural Land Reserve (ALR) since its inception in 1974. It answers the questions: How much has the total area of the ALR changed? How has this change affected the quality of ALR lands?

Until the 1970s nearly 6000 hectares of prime agricultural land were lost each year to urban and other uses. In response, the provincial government introduced the B.C. *Agricultural Land Commission Act* on April 18, 1973.

The Agricultural Land Commission (ALC), appointed by the provincial government, established a special land use zone called the Agricultural Land Reserve (ALR) to protect the dwindling supply of agricultural land. The ALR was established between 1974 and 1976 through cooperative efforts with regional districts and member municipalities, and included a public hearing process for local input. Initially it comprised 4.7 million hectares (5% of the province) (Figure 4).

The ALR includes private and public lands that may be farmed, grazed, forested, or vacant. Some ALR blocks cover thousands of hectares, but others are small pockets of only a few hectares. Although the area of ALR in the province has remained approximately the same, boundary changes have been made over the decades.

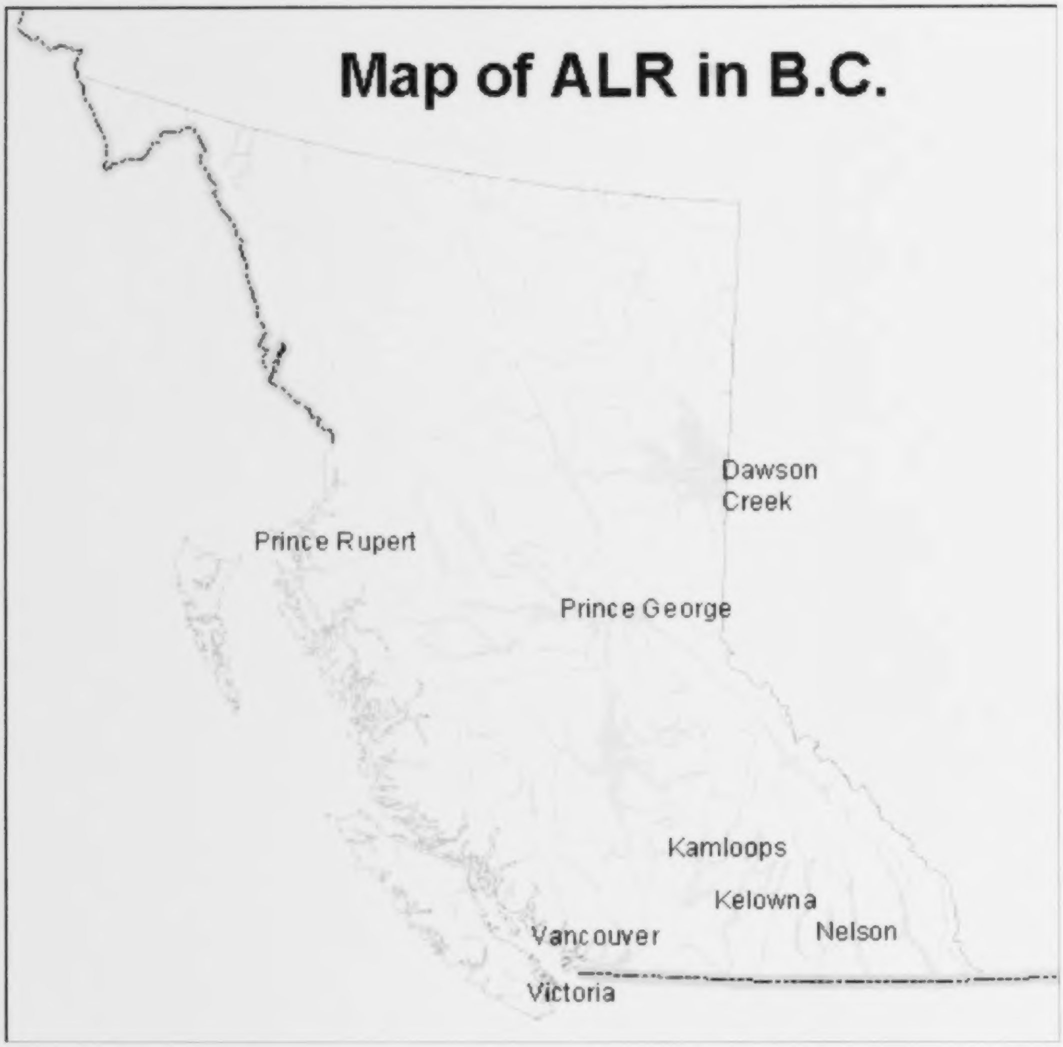
The chair of the ALC reports to the Minister of Agriculture and Lands, but the Commission operates independently within the framework of the *Agricultural Land Commission Act*.

The Commission has the authority to include or exclude land from the ALR. As a quasi-judicial organization, it reviews applications case-by-case, taking into consideration the following information: agricultural capability, suitability, current land use, the property in relation to surrounding lands, related agricultural concerns, community planning objectives, any other pertinent information specific to the property under application or proposal, and the broader provincial interest.

Agricultural land is used primarily for the production of food for human and livestock consumption. Agricultural activities also include growing plants for fibre and fuels (including wood), and for other products (e.g., pharmaceuticals, plant nursery stock).

All agricultural land is not equally capable of producing agricultural products. The main limiting factors in British Columbia are climate, topography, and soils. Climate determines the heat energy and moisture available for agricultural production. Topography restricts the ability to use cultivation equipment. In B.C., the inherent ability of land to produce agricultural crops is assessed through a classification system known as the "Land Capability Classification for Agriculture in British Columbia" (Kenk and Cotic 1983). Table 3 describes the seven agriculture land capability classes used in to the Canada Land Inventory (CLI) and the equivalent classes used by the ALC.

Figure 4. Distribution of Agricultural Land Reserve in B.C.


Map of ALR in B.C.
Dawson Creek
Prince Rupert
Prince George
Kamloops
Kelowna
Nelson
Vancouver
Victoria

Source: Agricultural Land Commission website, *www.alc.gov.bc.ca/mapping/Provincial_Map.htm*.

Table 3. Agricultural capability classes of the Canada Land Inventory (CLI) and the equivalent categories used by the Agricultural Land Commission (ALC)

Canada Land Inventory		Agricultural Land Commission	
Class	Capability for agricultural production	Category	Relation to CLI Capability Class
1	The very widest range of crops. Soil and climate conditions are optimum, resulting in easy management.	Prime	The entire unit is Class 1–3 inclusive
2	A wide range of crops. Minor restrictions of soil or climate may reduce capability but pose no major difficulties in management.	Prime Dominant	Over 50% of the unit is Class 1–3
3	A fairly wide range of crops under good management practices. Soil and/or climate limitations are somewhat restrictive.	Prime Subordinate	Less than 50% of the unit is Class 1–3
4	A restricted range of crops. Soil and climate conditions require special management considerations.	Secondary	Entire unit is Class 4–7
5	Cultivated perennial forage crops and specially adapted crops. Soil and/or climate conditions severely limit capability.		
6	Important in its natural state as grazing land. These lands cannot be cultivated due to soil and/or climate limitations.		
7	No capability for soil-bound agriculture.	Unclassified	No ratings have been assigned

Sources: Canada Land Inventory agricultural capability classes (Kenk and Cotic 1983) and ALC categories from ALC website: *www.alc.gov.bc.ca/alr/Ag_Capability.htm*.

Methodology and Data

All data for this indicator are from the ALC. Data on the total area of the ALR from 1974 to 2007 was updated by the ALC in May 2007 (Figure 5). The net change in ALR by agricultural capability category (Figure 6) was determined through an analysis of the tables in the ALC statistics report (ALC 2000). Areas included in the ALR are from Table B-6 (*www.alc.gov.bc.ca/publications/ALR_Stats/mar00/Part_B/Table_B-6.htm*). Areas excluded from the ALR were calculated by adding the totals for the two exclusion categories provided in Table C-6 (*www.alc.gov.bc.ca/publications/ALR_Stats/mar00/Part_C/Table_C-6.htm*) and Table E-6 (*www.alc.gov.bc.ca/publications/ALR_Stats/mar00/Part_C/Table_C-6.htm*).

Regional summaries of exclusions and inclusions and net changes by capability category (Figure 7) were also produced from these tables. For this analysis, the regional districts were grouped into six larger regions following the map on the ALC webpage: *www.alc.gov.bc.ca/contacts/regions.htm*.

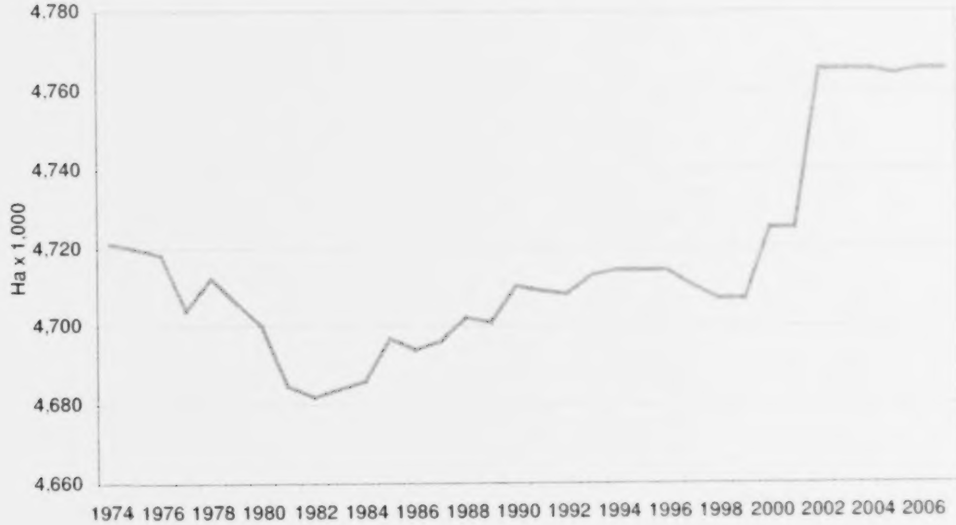
The total area in the ALR (Table 4, Figure 5) increased by 1% (43,903 ha) between 1974 and 2007. Most (26,729 ha) of this increase was in lands in the secondary capability category, but there was some decrease in the prime and prime subordinate capability categories (Figure 6). The largest inclusion of secondary capability agricultural lands (81,052 ha) was in northern B.C.; there were losses in this category in the southern part of the province, especially in the Okanagan (18,228 ha) and on Vancouver Island (15,727 ha) (Figure 7, Table 5). There was a net decrease (7,914 ha) in prime agricultural land in all regions of the province, but mostly in the Okanagan and the South Coast. The unclassified lands (Figure 7) in the interior and northern parts of the province are all likely secondary capability lands that have not yet been classified (S. Runka, ALC, pers. comm.).

Table 4. Total area (cumulative ha) in the ALR, 1974 to 2007.

Year	Area of ALR (ha)
1974	4,720,675.9
1975	4,720,038.5
1976	4,718,197.1
1977	4,703,572.6
1978	4,712,177.0
1979	4,705,675.3
1980	4,699,786.1
1981	4,684,594.4
1982	4,682,016.6
1983	4,684,005.3
1984	4,686,503.0
1985	4,696,715.8
1986	4,693,860.1
1987	4,696,143.5
1988	4,701,619.0
1989	4,701,386.3
1990	4,709,993.4
1991	4,708,687.1
1992	4,707,609.4
1993	4,712,629.7
1994	4,713,864.5
1995	4,713,789.1
1996	4,714,083.3
1997	4,709,700.8
1998	4,707,431.7
1999	4,707,528.5
2000	4,724,950.9
2001	4,725,371.0
2002	4,765,202.7
2003	4,764,884.7
2004	4,765,076.1
2005	4,764,539.0
2006	4,764,754.5
2007	4,764,579.0

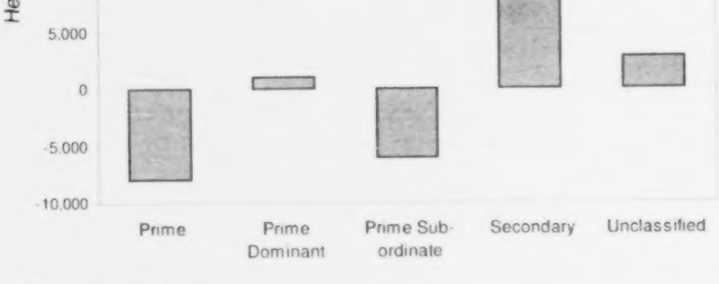
Source: Data provided by the Agricultural Land Commission, 2006. Data for 2007 is from 2006/07 ALC Annual Service Plan Report: *www.bcbudget.gov.bc.ca/Annual_Reports/2006_2007/alc/alc.pdf.*

Figure 5. Total area (ha) in the ALR from 1974 to 2007.



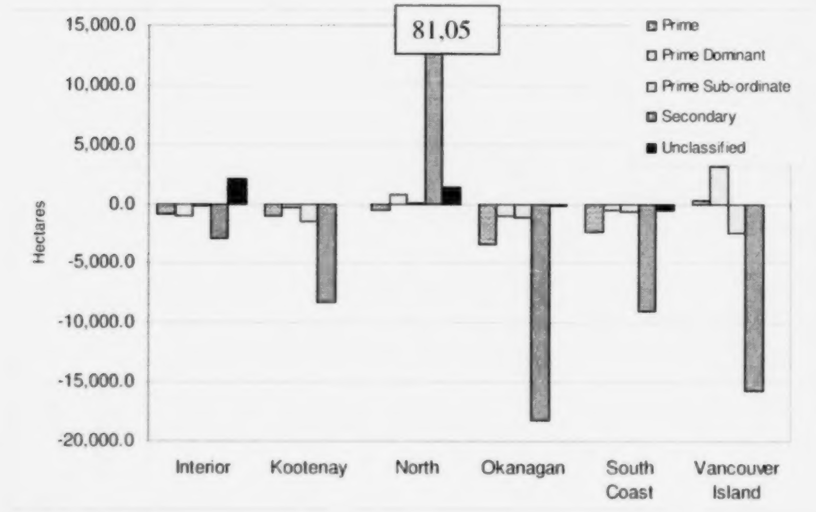
Source: Data provided by the Agricultural Land Commission, 2006. Data for 2007 is from 2006/07 ALC Annual Service Plan Report: *www.bcbudget.gov.bc.ca/Annual_Reports/2006_2007/alc/alc.pdf*.

Figure 6. Net change in ALR by agricultural capability category, 1974 to March 2000.



Source: ALC 2000.

Figure 7. Net change in agricultural capability category of the ALR, by region, 1974 to March 2000.



Source: ALC 2000.

Table 5. Net change in total area of ALR from 1979 to 31 March 2000, by region and agricultural capability category.

		Area by agricultural capability category (ha)				
Region	Total area (ha)	Prime	Prime Dominant	Prime Subordinate	Secondary	Unclassified
Interior						
Inclusion	17,565.8	461.2	343.2	926.0	13,705.3	2,130.1
Exclusion	20,251.7	1313.6	1,334.4	1,037.3	16,566.4	0.0
Net change	–2,685.9	–852.4	–991.2	–111.3	–2,861.1	2,130.1
Kootenay						
Inclusion	1,316.0	356.6	44.7	190.0	721.2	3.5
Exclusion	12,536.4	1,365.6	371.1	1,732.8	9,048.4	18.5
Net change	–11,220.4	–1,009.0	–326.4	–1,542.8	–8,327.2	–15.0
North						
Inclusion	98,123.5	628.6	1,315.0	885.1	93,930.3	1,364.5
Exclusion	15,418.5	1,178.6	532.4	829.4	12,878.1	0.0
Net change	82,705.0	–550.0	782.6	55.7	81,052.2	1,364.5
Okanagan						
Inclusion	3,028.2	504.8	71.1	164.1	2,288.2	0.0
Exclusion	27,001.2	3,884.8	1,111.7	1,327.1	20,516.0	161.6
Net change	–23,973.0	–3,380.0	–1,040.6	–1,163.0	–18,227.8	–161.6
South Coast						
Inclusion	1,608.8	856.3	161.5	120.5	440.5	30.0
Exclusion	14,744.0	3,236.5	678.6	804.8	9,497.3	526.8
Net change	–13,135.2	–2,380.2	–517.1	–684.3	–9,056.8	–496.8
Vancouver Island						
Inclusion	8,040.8	2,638.8	3,523.0	217.2	1,661.8	0.0
Exclusion	22,777.4	2,381.2	344.7	2,639.9	17,389.1	22.5
Net change	–14,736.6	257.6	3,178.3	–2,422.7	–15,727.3	–22.5
B.C. Total						
Inclusion	129,683.1	5,446.3	5,458.5	2,502.9	112,747.3	3,528.1
Exclusion	113,116.5	13,360.3	4,392.9	8,615.3	86,018.6	729.4
Net change	16,566.6	–7,914.0	1,065.6	–6,112.4	26,728.7	2,798.7

Source: Agricultural Land Reserve Statistics 31 March 2000: *www.alc.gov.bc.ca/publications/ALR_Stats/mar00/Part_E/Table_E-6.htm.*

Interpretation

The net change in the size of the ALR is an indicator of the stability of the agricultural land base. A relatively stable or increasing net size of the ALR would indicate that lands suitable for agriculture are being retained in the ALR (ALC 2007). There was a decline in area of the ALR between 1974 and the mid 1980s. Much of this loss was likely due to adjustments to the initial boundaries (which were based on preliminary technical maps from the Canada Land Inventory) as more detailed technical land capability information became available (Runka 2006). Between 1999 and 2002, the total area of land within the ALR increased above the initial area at the inception of the ALR in 1974. This change resulted from a large inclusion of Crown land in 2002 in the northern part of the province as recommended by provincial land and resource use planning tables. Since 2002, the total amount of land in the ALR has remained essentially unchanged.

The agricultural capability of the land that has moved into or out of the ALR is significant as it indicates the overall agricultural value of the lands in the ALR. Although lands with secondary agricultural capability cannot grow as wide a range of crops as can prime capability lands, they are important for many agricultural uses, such as grazing and growing feed crops. Much of the secondary capability lands added to the northern part of the province are likely used for these purposes.

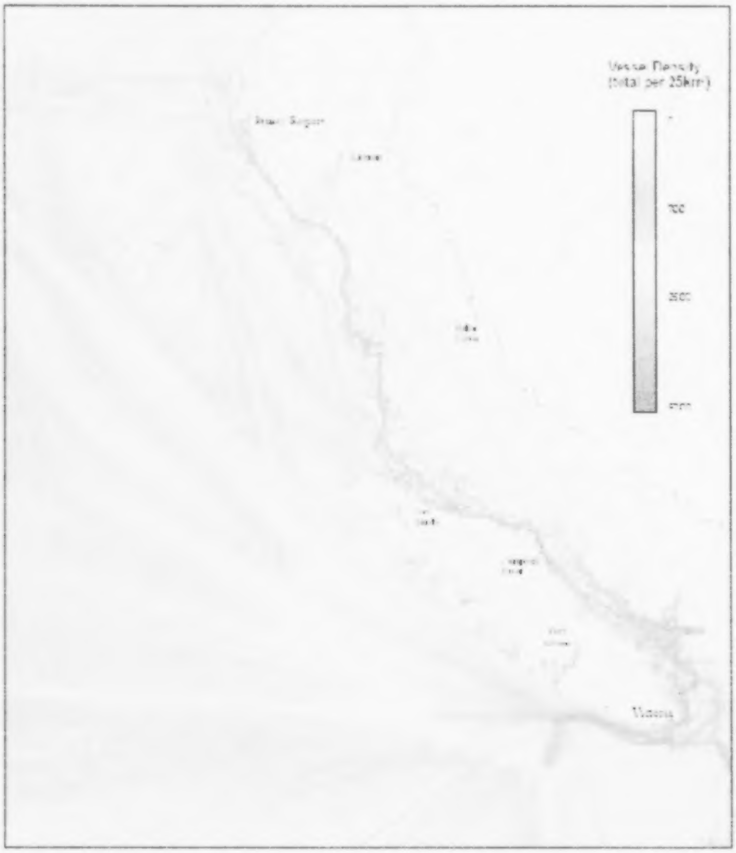
The loss of prime agricultural land in the ALR is particularly noticeable in the Okanagan and South Coast where the population is highest and the demand for land for development is the greatest. However, the loss of agricultural land undoubtedly would have been significantly higher if the ALR did not exist. For example, according to Smart Growth BC, although the population in Metro Vancouver has consistently increased since the mid-1970s, the region's annual rate of ALR loss has declined steadily since 1983. In effect, without the ALR, Metro Vancouver would have converted approximately 7000 additional hectares to urban development (Smart Growth BC 2005).

Supplementary Information: Density of marine traffic on the B.C. coast

On the coast, marine traffic is as essential a mode of transport for people and goods as the highways are for land-based traffic. Marine traffic, however, affects marine ecosystems when it is a source of disturbance and pollutants, whether from sewage discharge or bilge cleaning, or from accidents and spills. Noise from motors and activity can disturb wildlife, particularly marine mammals and birds. Recreational use of marine parks, ecological zones, and other areas can also disturb wildlife and habitats. Marine vessel motors emit pollutants that contribute to regional and local air pollution in airsheds such as the lower Fraser Valley. As well, international shipping traffic increases the risk of introducing exotic and invasive species carried on ship hulls and in ballast water.

The following is a summary of an analysis of vessel movement patterns that was reported in the B.C. Coastal Environment 2006 report (BCMOE 2006a) (see *www.env.gov.bc.ca/soe/bcce/01_population_economic/marine_traffic.html*).

Figure 8: Marine traffic vessel density (per 25 km^2) along the coast of B.C. in 2003.



Source: Marine Communications and Traffic Service, Canadian Coast Guard.

An analysis of the average annual vessel movements for the different types of vessels found that passenger vessels (ferries and cruise ships) accounted for about 300,000 vessel movements per year or 56% of the total. Tugs towing or propelling barges accounted for more than 117,000 movements per year, or 29% of the marine traffic on the coast. Oil, gas, and chemical tankers accounted for around 4,000 vessel movements annually, or around 1% of traffic.

Victoria, Vancouver, and Juan de Fuca Strait VTS zones have the highest traffic volumes. In this area, with the province's highest population, high marine traffic volumes are one more of many stresses on marine ecosystems. This region is also critical habitat for the southern resident population of killer whales, which range through this area throughout the year, but especially during salmon migrations.

Three other shipping routes—the Inside Passage, Hecate Strait, and the west coasts of Vancouver Island and the Queen Charlotte Islands—have considerable activity, but are not as heavily used as the southern routes. With the expansion of the port at Prince Rupert, traffic volume along the north coast will continue to increase in future.

The impact of shipping, in terms of number and type of ships, can also vary seasonally on some routes. The Marine Communications and Traffic Service (MCTS) annual summary data show that overall shipping traffic is greater in summer than in winter and varies according to vessel type (P. O'Hara, UVic/CWS/DFO, pers. comm., 2005). The distribution of bulk carrier, cargo, and tanker traffic does not change much seasonally, but fishing vessel traffic is seasonal because it depends on fishery openings. Cruise ship traffic is also seasonal, with the heaviest traffic during the summer. Seasonality of marine traffic is important because of its potential impacts on wildlife seasonal habitats, such as nesting seabirds, migrating salmon, and coastal wintering birds.

Liquid and Solid Waste Management

3. Key Indicator: Level of municipal wastewater treatment in B.C.

Wastewater treatment is a response indicator. It shows the management response to wastewater (also referred to as sewage) disposal in B.C. Ideally, as more of the population is served by higher levels of wastewater treatment, there is potential reduction in environmental impact.

By volume, municipal sewage and combined sewer overflows are one of the largest point sources of pollution to Canadian waters. In addition to human waste, wastewater may also contain motor oil, paint thinner, antifreeze, pesticide residues, pharmaceuticals, solvents, heavy metals, and other pollutants. The release of untreated or inadequately treated wastewater may put people at risk if drinking water becomes contaminated with micro-organisms or toxic substances. People are also put at risk from consuming fish and shellfish from contaminated waters (see Indicator 4: Trends in shellfish closures).

The main sources of wastewater are households, industrial operations, commercial operations, and stormwater runoff. In Canada, it is estimated that 80% of marine pollution comes from terrestrial activities, including industrial and agricultural runoff (DFO 1997).

The purpose of wastewater treatment is primarily to protect human health and to reduce stress on the receiving environment. Before sewage is discharged to the environment, it is treated to remove some impurities and to reduce the biological oxygen demand (BOD) and total suspended solids (TSS). The level of treatment used by a municipality is an indicator of the amount of pollutants being discharged to the environment in sewage effluent. With each increase in the level of treatment, the BOD and TSS are further reduced.

This indicator shows the proportion of the municipal population with sewage treatment that is served by preliminary, primary, secondary, or tertiary wastewater treatment.

Methodology and Data

The 2004 data come from the Municipal Water and Wastewater Survey (MWWS; Environment Canada 2005a), formerly Canada's Municipal Water Use Database (MUD). Data for 1999 and previous years come from the MUD and the B.C. government's *Summary of Municipal Treatment Facilities* (BCMWLAP 2001).

Although the survey database underwent changes in 2004, when MWWS replaced the previous MUD surveys, the phrasing of key questions in the 2004 survey conformed as closely as possible to that of previous years so as not to obscure emerging trends. (For details on changes, see *www.ec.gc.ca/water/en/info/pubs/sss/e_mun2001.htm*.)

MWWS lists a host of water and sewage data for all municipalities that have a population of 1,000 or more. This includes the population served by preliminary, primary, secondary (includes ponds and lagoons), and tertiary treatment.

The treatment levels are defined as follows:

- **Preliminary:** Grit and solid material are screened out before the sewage is treated or released into the environment.
- **Primary:** Solids are separated from the liquids; floatable solids, oil, and grease are usually skimmed off the surface of the wastewater.
- **Secondary:** After primary treatment, further treatment may include biological treatment. It further reduces the amount of contaminants by fostering the consumption of organic material by organisms in the wastewater. Infiltration ponds and lagoons are included as secondary treatment.
- **Tertiary:** Further treatment to reduce TSS and BOD and remove specific contaminants. The particular technologies used depend on the characteristics of the sewage.

The data in MWWS are from a self-reporting survey, therefore the quality of the data depends on the accuracy of the respondents, their interpretation of the questions, the response rate of municipalities, and the number of municipalities surveyed. At times individual municipalities report their figures as estimated values or carry over figures from a previous year's report.

Earlier MUD surveys (1999 and previous years) included preliminary treatment with the primary treatment category. Because of the differences in impact on the receiving environment, it is important to separate preliminary treatment from primary treatment. Therefore, for 1999 and previous years, data for municipalities served by preliminary treatment were obtained from the *Summary of Municipal Treatment Facilities* (BCMWLAP 2001) or by contacting individual municipalities. Although a category for preliminary treatment was included in the 2004 MWWS, the population in the core of Victoria, which is served by preliminary treatment only, did not show up in this category.

The data in Table 6 and Figure 9 were derived by dividing the population served for each treatment type by the total population serviced by wastewater treatment and converting to percentages. The total population is an aggregation of all those served by preliminary, primary, secondary, and tertiary treatment for all of the listed municipalities.

Table 6. Population of B.C. served by each level of waste treatment facility.

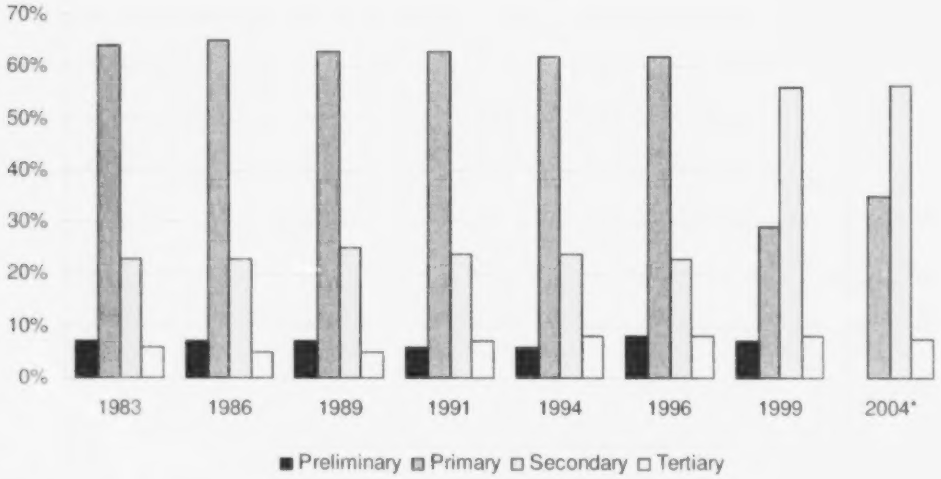
Year	Municipal population with treatment**	Proportion of municipal population with			
		Preliminary	Primary	Secondary	Tertiary
1983	1,990,863	7%	64%	23%	6%
1986	2,007,356	7%	65%	23%	5%
1989	2,264,064	7%	63%	25%	5%
1991	2,422,783	6%	63%	24%	7%
1994	2,626,018	6%	62%	24%	8%
1996	2,865,142	8%	62%	23%	8%
1999	2,986,973	7%	29%	56%	8%
2004*	3,059,509	0	35%	56.4%	7.5%

Sources: 2004 data, Environment Canada Municipal Wastewater and Water Survey 2005a; 1983–99 data, Environment Canada, Municipal Water Use Database (MUD), and BCMWLAP 2001.

* Although MWWS 2004 methodology was similar to previous surveys, it does not show a figure for population with preliminary treatment (as currently in place for the core of Victoria).

** Total population served by wastewater treatment facilities; remaining population (approximately 20%) has on-site sewer systems regulated under the Ministry of Health.

Figure 9. Proportion of the B.C. population served by each level of waste treatment (1983–1999 and 2004).



Sources: 2004 data, Environment Canada 2005a; 1983–99 data, Environment Canada, Municipal Water Use Database (MUD), and BCMWLAP 2001.

Interpretation

This indicator was last reported in the previous Environmental Trends report (BCMWLAP 2002), citing 1999 data from the Environment Canada Municipal Water Use Database. In 1999, there was a large increase in the population with secondary treatment because the Annacis Island treatment plant was upgraded from primary to secondary treatment. Since that time, there has been little change, because there have been no major treatment plant upgrades or construction of new facilities. The slight differences between the reported 1999 and 2004 figures for secondary and tertiary treatment are not likely significant; in particular, the slight reduction in population with tertiary treatment over those two surveys likely does not reflect a real decrease in treatment level.

The proportion of population with higher levels of treatment is not expected to change until the core area of Victoria, which currently has preliminary treatment, is served by a treatment plant or until there are upgrades to other large treatment plants.

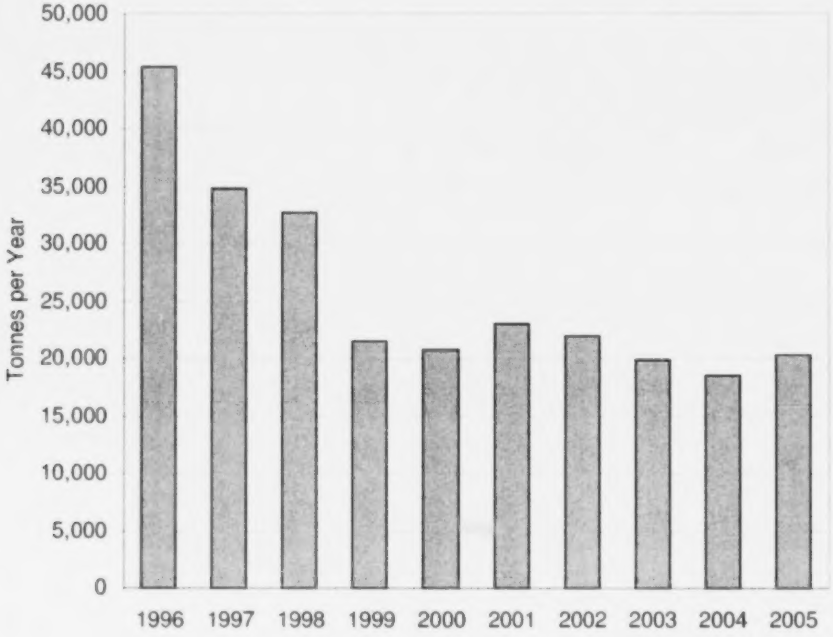
Supplementary Information: Reducing the impact of sewage discharge in Metro Vancouver

Metro Vancouver (formerly the GVRD) is serviced by five wastewater treatment plants that together treat an average of 1.2 billion litres of wastewater per day. About half of this volume receives primary treatment at the Iona and Lions Gate plants, which discharge to the marine environment. The remaining three plants (Annacis, Lulu, and Langley) provide secondary treatment and discharge to the Fraser River. Even though the population of the region has increased over the past 10 years, the total discharge of wastewater has remained fairly consistent at 1.2 billon litres per day. This is mostly explained by the separation of some of the combined sewer systems in Metro Vancouver during this period.

Biological oxygen demand (BOD) is a measure of how much oxygen is needed by micro-organisms to break down organic matter present in wastewater. It is an indicator of the effectiveness of the treatment process, with lower BOD indicating improving conditions. Figure 10 shows the trend in annual wastewater BOD from Metro Vancouver treatment plants.

The dramatic drop in BOD after 1996 was a result of the upgrade of the Annacis and Lulu plants from primary to secondary treatment. In addition to the decrease in BOD, the switch to secondary treatment was found to have significantly reduced the concentrations of copper, lead, manganese, zinc, chromium, oil and grease, and phenol in the effluent.

Figure 10. Trend in BOD from effluent discharge in Metro Vancouver (tonnes per year).



Source: GVRD 2006.

4. Secondary Indicator: Trends in shellfish closures due to sewage contamination

This is an impact indicator. It addresses the question: What are the impacts of human activities on coastal ecosystems? The area of shellfish beds closed due to fecal contamination is used as a surrogate for the area of impact from sewage and other human sources.

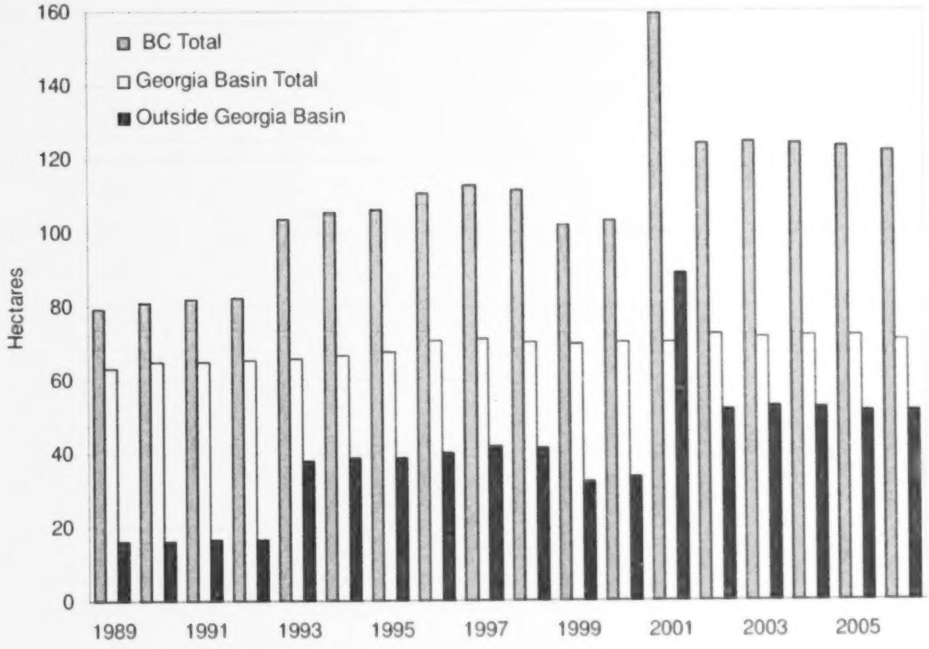
Fecal coliform bacteria indicate the presence of human or animal wastes and the possible presence of other disease-causing organisms. Areas of shellfish beds are closed when they are found to be contaminated with fecal coliform bacteria. Marine contamination from these bacteria comes from a variety of sources, including urban runoff, sewage discharge, and agricultural drainage. Sporadic outbreaks of contamination also come from wildlife sources.

This indicator was reported in detail in the B.C. Coastal Environment 2006 report (BCMOE 2006a) and is updated here (see: *www.env.gov.bc.ca/soe/bcce/01_population_economic/shellfish_closures.html*).

Methodology and Data

Data were obtained from Environment Canada, Ecosystem Information Section, and Fisheries and Oceans Canada. Environment Canada monitors the sanitary quality of shellfish-growing waters on the B.C. south coast, including 2600 ha of coastal waters used for shellfish aquaculture and about 750,000 ha used for wild shellfish harvesting. Areas are closed to harvesting if fecal coliform counts exceed specified standards. (Note that the data do not include closures for paralytic shellfish poisoning.)

Figure 11. Trends in the area (ha) of shellfish beds closed to harvesting in B.C., 1989–2006.



Source: Environment Canada 2005b.

Interpretation

The increase in area of shellfish closures is primarily a result of increasing population and associated sewage discharges. Before 1976, less than 60,000 ha of shellfish growing area was under closure orders. The area increased to about 80,000 ha in 1990, and continues at about 121,000–124,000 ha since 2002.

Outside of the Georgia Basin, the shellfish harvest area under closure increased more than threefold from 1989 to 2004, partly a result of expanded monitoring programs, as well as growing development along shorelines (Environment Canada 2005b). The spike in 2001 reflects a 46,000-ha temporary seasonal closure in Clayoquot and Barkley sounds that is believed to have been caused by contamination from wildlife sources.

Georgia Basin locations represented 58% (72,000 ha) of the area closed to shellfish harvesting in 2004. The closure area within the Georgia Basin has remained stable partly because an extensive area was already closed, particularly in the Burrard Inlet, Fraser River estuary, and Boundary Bay areas. Remedial programs have removed only small areas from the sanitary closure restrictions.

In some locations (such as the Queen Charlotte Islands), new closures are a result of an increase in the extent of monitoring and assessment of shellfish areas. In other instances, reductions in area are due to water quality restoration initiatives and the reassessment of temporary closures.

Inadequate sewage treatment is only one cause of elevated levels of fecal coliform bacteria. Often multiple and complex sources are responsible, particularly in the lower Georgia Basin; sources include non-point sources such as poorly placed or maintained septic tanks outside of the sewered areas, agricultural and urban runoff, and discharge from marine vessels.

5. Key Indicator: Municipal solid waste disposed and recycled per person in regional districts in B.C.

The annual amount of solid waste disposed of per capita is a pressure indicator. The disposal of solid waste directly reflects consumption patterns by British Columbians and represents a lost opportunity to collect material resources that are being landfilled.

The materials entering our landfills consist of waste that is composed of organic, in-organic material, and toxic substances contained in products. The waste sent to landfill is a potential source of contamination for groundwater, soil, and air. Landfills also use large tracts of land, which are becoming difficult to accommodate in densely populated areas.

Disposal of solid waste in landfills indicates wasted resources and wasted energy embodied in the discarded material. For example, over-packaging results in energy and resources being spent on materials that are used briefly, then enter the waste stream. Many plastic goods also represent wasted energy and resources because recycling them really means "down-cycling" and just prolonging the life of plastic through one more product cycle before it is too degraded to re-use (i.e., Mcdonough and Braungart 2002).

In 2004, it was estimated that residential waste accounted for 35% of the municipal waste stream in B.C., with the rest coming from industrial, commercial, and institutional sources (Statistics Canada 2004). Programs to reduce the amount of disposed waste and increase recycled waste have been in place in the province for more than 15 years, longer in some areas. In 1989, the government of British Columbia adopted a goal established by the Canadian Council for Ministers of the Environment to cut municipal waste by 50% per capita by the year 2000 (compared to 1990 levels). At the same time the province introduced the requirement for regional districts to develop and submit Solid Waste Management Plans for approval.

Methodology and Data

In 1990, when the province established the requirement for regional districts to develop and implement Solid Waste Management Plans, it became important to track the waste being disposed and diverted for recycling.

Data for this indicator are from provincial waste tracking reports which, since 1996, have been prepared by the Recycling Council of British Columbia (RCBC) under contract to the Ministry of Environment. Reports are available at: *www.env.gov.bc.ca/epd/epdpa/mpp/reduction.htm*. The waste tracking reports do not include recycled data after 2000 because the material diverted through municipal recycling programs is not tracked consistently by local governments. The diversion of materials recycled through industry stewardship programs for paints, beverage containers, etc., is reported separately later in this report.

It is important to note that data submitted by regional districts vary in accuracy and completeness, depending on factors such as the availability of staff or weigh scales at disposal sites. Information is generally more accurate for urban areas than for rural areas, because the former are mostly served by larger and more sophisticated waste facilities that have weigh scales and tipping fees. In contrast, many rural facilities are not staffed and/or lack scales or tipping fees (RCBC 2007).

Of the 27 regional districts 25 supplied municipal solid waste disposal data for 2003 to 2005. Comox-Strathcona did not provide data and Okanagan-Similkameen provided partial data; their combined population is 4.4% of the provincial total. Data for these two districts were estimated by multiplying their 2003, 2004, and 2005 populations by the 2002 disposal rate. Provincial and regional district population figures were obtained from BC Stats (2006). Disposed and recycled municipal solid waste for 1990 and 1996–2005 is shown in Figures 12 and 13 and Table 7.

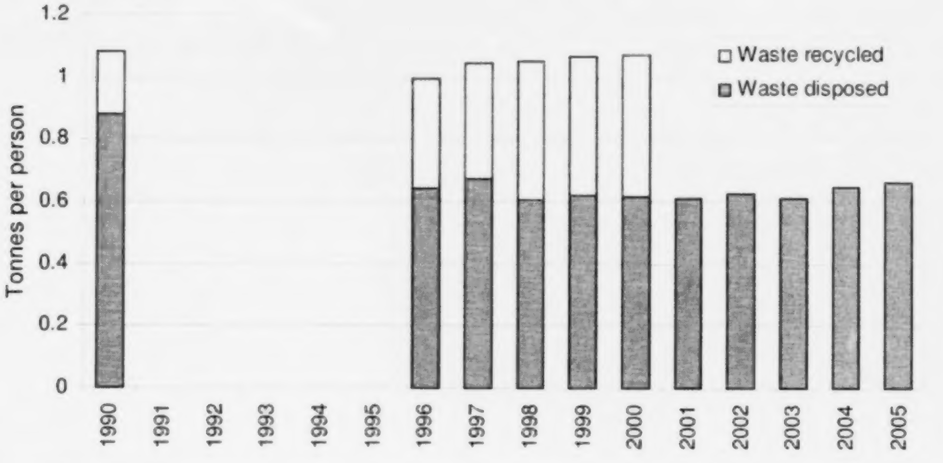
Table 7. Municipal solid waste disposed and recycled in B.C., 1990–2005.

		Municipal solid waste (tonnes)			
Year	Population	Total disposed to landfills & incinerators	Total recycled	Disposed per capita	Recycled per capita
1990	3,289,259	2,890,516	659,764	0.879	0.2005813
1996	3,880,593	2,448,741	1,363,721	0.641	0.3514208
1997	3,958,217	2,650,108	1,493,022	0.67	0.3771956
1998	3,996,030	2,423,524	1,771,813	0.606	0.4433933
1999	4,026,657	2,504,667	1,790,666	0.622	0.4447029
2000	4,062,270	2,509,112	1,837,381	0.618	0.452304
2001	4,101,579	2,509,088	*	0.612	*
2002	4,141,272	2,602,716	*	0.628	*
2003	4,154,591	2,529,251	*	0.609	*
2004	4,201,867	2,714,172	*	0.646	*
2005	4,254,522	2,822,067	*	0.663	*

Sources: Municipal solid waste data: RCBC 2004, 2007; population statistics: BC Stats 2006.

* Data for total waste recycled have not been collected by MOE from the regional districts since 2000.

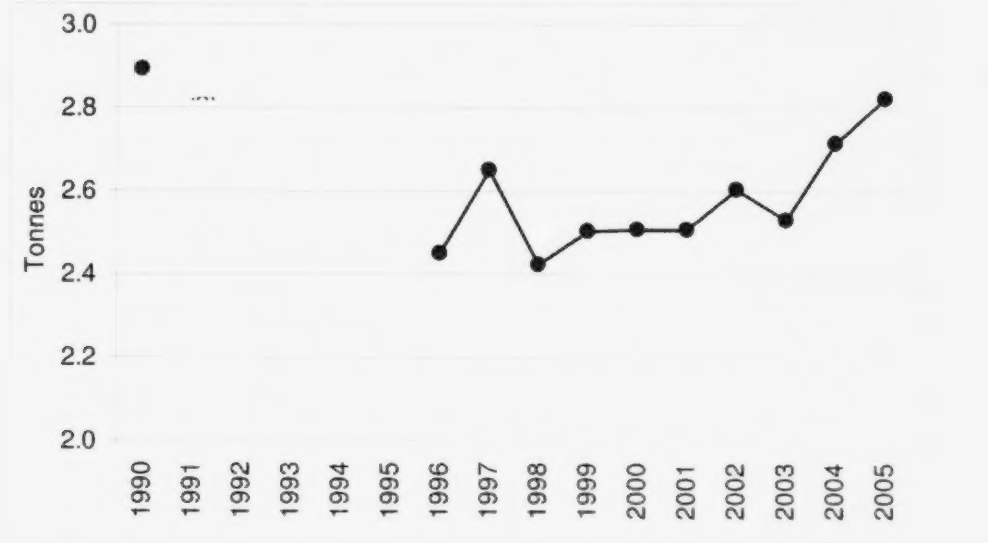
Figure 12. Municipal solid waste (in tonnes) disposed and recycled per person in B.C., 1990–2005.



Sources: Municipal solid waste data, RCBC 2004 and RCBC 2007; population statistics, BC Stats 2006.

* Data for total waste recycled have not been collected by MOE from the regional districts since 2000.

Figure 13. Total municipal solid waste (in tonnes) disposed (to landfills and incinerators) in B.C., 1990–2005.



Sources: RCBC 2004, 2007.

This indicator is limited to one aspect of the waste stream: municipal waste. It does not address hazardous, biomedical, or other wastes that may be considered part of the larger waste stream.

Interpretation

In 2005, the overall provincial disposal rate was 0.663 tonnes per person, down from 0.879 tonnes per person in 1990. This is a 24.5% reduction in the per capita amount of municipal solid waste disposed between 1990 and 2005. Between 1990 and 2005, there was a slight drop (2.4%) in the amount of total waste disposed per year, from 2,890,516 tonnes to 2,822,067 tonnes. During that same period the provincial population increased by 29%. Waste reduction initiatives were successful in keeping the total amount of waste disposed of annually to essentially the same volume that it was in 1990, despite a substantial increase in population over the 15 years.

In recent years, however, the rate of municipal solid waste disposal has been increasing faster than the population increase, resulting in increasing amounts of waste disposed per person. Between 2003 and 2004, the B.C. population increased by only 1.1%, but there was a 7.3% increase in the total amount of waste disposed. Between 2004 and 2005, the population increased by 1.25%, but there was a 3.9% increase in the amount of waste that ended up in landfills and incinerators.

Supplementary Information: Municipal solid waste disposal per capita in regional districts in B.C.

Trends in municipal solid waste reduction vary widely between regional districts. Over the 15 years from 1990 to 2005 trends ranged from a 66% decrease in waste per person (Powell River) to an increase of more than 60% per person (Alberni-Clayoquot). Trends depend on municipal solid waste reduction initiatives undertaken by each regional district and on the capability of each regional district to track disposal. The disposal rate is generally a function of the waste reduction plans put in place by each regional district, as well as the recycling facilities and programs available to residents in that regional district.

Generally, regional districts in areas with higher population density are under the most pressure to reduce the per capita disposal rates of municipal solid waste. Areas with high populations generate a relatively large amount of solid waste per area, yet there is less land available to set aside as landfill for this waste. In these areas, regional districts generally have a longer history of actively pursuing recycling initiatives and education programs to reduce waste generation.

Table 8. Net change in regional district disposal rates per capita (tonnes of waste going to incinerators and landfills), 1990 to 2005.

Regional District	1990	2005	% change,	Rank
Powell River	0.66	0.23	−66.1	1
Squamish-Lillooet	1.20	0.55	−53.8	2
Fraser Valley	1.08	0.50	−53.7	3
Cowichan Valley	0.89	0.42	−53.4	4
Kootenay-Boundary	0.82	0.47	−42.5	5
Sunshine Coast	0.84	0.49	−41.3	6
Mount Waddington	0.87	0.53	−39.2	7
North Okanagan	0.98	0.65	−33.3	8
Central Coast	0.38	0.26	−32.8	9
Bulkley-Nechako	0.66	0.47	−29.2	10
Greater Vancouver*	1.03	0.73	−29.0	11
Comox-Strathcona	0.65	0.47	−28.7	12
Central Kootenay	0.68	0.49	−26.9	13
Kitimat-Stikine	0.65	0.48	−26.2	14
Capital (Victoria area)	0.60	0.45	−24.8	15
Okanagan-Similkameen	1.21	1.00	−17.0	16
Columbia-Shuswap	0.69	0.60	−12.1	17
Central Okanagan	0.55	0.49	−11.2	18
Northern Rockies	1.80	1.70	−5.8	19
Nanaimo	0.51	0.50	−3.5	20
Thompson-Nicola	0.66	0.69	+4.1	21
Cariboo	0.37	0.41	+8.6	22
Peace River	0.85	0.97	+13.5	23
Fraser-Fort George	0.65	0.81	+24.9	24
East Kootenay	0.63	0.87	+38.1	25
Alberni-Clayoquot	0.52	0.84	+61.0	26
Skeena-Queen Charlotte	0.74	no data**		

Sources: RCBC 2004, 2007; population statistics, BC Stats 2006.

* For their own comparisons, Metro Vancouver (GVRD) prefers to calculate total disposal reductions based on waste generation (rather than waste disposed) to reflect the higher amount of recycling that may have been done in the regional district before 1990 than in other regional districts. That method shows a 48% reduction in the Metro Vancouver per capita disposal rate.

** Due to a substantial discrepancy between 2002 and 2003–2005 disposal data provided by Skeena-Queen Charlotte, figures were not reported to avoid under- or over-estimating disposal rate.

6. Secondary Indicator: Trends in waste diversion through industry-led product stewardship programs

This is a response indicator. It answers the questions: What is the result of product stewardship programs in B.C.? How much waste is successfully collected and diverted from landfills?

The history of product stewardship programs dates back to 1991 when B.C. started recycling programs for scrap tires and lead-acid batteries. Over the next several years, the province implemented a recycling program for used lubricating oil and established a network of collection depots for household hazardous waste. However, these early programs were government operated and consumer funded, with little industry involvement.

Industry-led product stewardship programs began in 1997, when two regulations were approved: (1) the Post-Consumer Residual Stewardship Program Regulation, requiring producers and consumers to manage leftover and waste flammable liquids, gasoline, domestic pesticides, and pharmaceuticals; and (2) the Beverage Container Stewardship Program Regulation, requiring brand-owners to collect ready-to-serve beverage containers (excluding milk and milk substitutes) with a deposit–refund system.

In 2004, after input from stakeholders, a streamlined Recycling Regulation was enacted to replace previous regulations and paved the way to expand industry product stewardship programs in B.C. The intent of the Regulation is to make regulated producers entirely responsible for managing the lifecycle of their products.

The province reviews the stewardship plans after satisfactory public consultation is complete. For approved plans the industry implements its program by collecting end-of-life products from the consumer at retail or through a depot system.

Internationally, product stewardship is commonly referred to as extended producer responsibility (EPR). The Organization for Economic Co-operation and Development has developed four goals for EPR:

- Reduce waste at the source to conserve natural resources and materials.
- Prevent waste.
- Design products to be more compatible with the environment.
- Promote sustainable development by closing materials-use loops.

EPR strategies have been implemented in many jurisdictions, including Canada. For more information on EPR see *www.ec.gc.ca/epr/ and www.env.gov.bc.ca/epd/epdpa/ips/.*

In British Columbia, there are currently eight stewardship programs that deal with collection and processing of products at the end of their useful life.

- Household paint, solvents, flammable liquids and gasoline, and pesticides. The Product Care Association, an industry-sponsored, not-for-profit association, operates collection depots across B.C. to collect leftover (residual) household paints, solvents, flammable liquids, gasoline, and pesticides. Paint is managed in one of three ways: reused by giving them to other consumers through the Paint Exchange program (4% of collected paint in 2005); recycled by reprocessing as paint or using it in concrete or cement manufacture (62% in 2005); or used for energy recovery by using the product as an alternative energy source in cement kilns and other operations (34% in 2005). In 2005, all solvents, flammable liquids, and gasoline were used for energy recovery, and all pesticides were incinerated in licensed facilities due to contamination (Product Care 2006). None of the collected products went to landfill facilities. Wherever possible, metal and plastic containers were recycled.

- Tree-marking paint. Tree-marking paint is used in the forest industry and by surveyors to identify trees, cutting boundaries, roads, and other surfaces. Ninety percent of this product category is tree-marking paint, but the category also includes "upside-down paint" (sometimes called survey paint), which is sprayed in an inverted position. Household paints are not included in this stewardship program. The program is run by the Tree-Marking-Paint Stewardship Association, a not-for-profit, industry-sponsored agency.

  Recovered tree-marking paint containers are processed either by the forest company itself or by the brand owner. Processing involves evacuating paint from cans and burning the residuals (estimated at 200 litres of residual paint for every 7000 empty containers) for energy recovery (2005 Annual Report; TSA 2006). Once the residual paint has been processed, the containers go to local community facilities for plastic and cardboard recycling, and cans are recycled for scrap metal.

- Used oil, oil filters, and oil containers. The British Columbia Used Oil Management Association (BCUOMA) manages a stewardship program to collect used oil, oil filters, and oil containers. The program is based on brand owners paying an Environmental Handling Fee to BCUOMA, which then subsidizes the transport of used oil, filters, and containers through Return Incentives (RIs). Recovery rates for 2006 were 70.7% of the oil available for collection (BCUOMA 2006 Annual Report). About half of the recovered oil is re-refined to restore its original lubricating characteristics, and the remainder is used as fuel in pulp mills and asphalt plants. Oil filters are shredded, centrifuged to recover oil, then washed and mixed with other plastics. The pelletized product is then sold for use in manufacturing new oil containers or other plastic products.

- Scrap tires. In 2006, a tire product category was added to the Recycling Regulation to transfer the government-operated Financial Incentives for Recycling Scrap Tires program to an industry stewardship program. On January 1, 2007, Tire Stewardship BC began managing B.C.'s scrap tire recycling program. Most of the collected scrap tires are either used as fuel in cement kilns (typically, less than one-third of the tires are used in this way), or converted into crumb rubber and then used to manufacture products such as sport floors and playground surfaces (TSBC, undated).

- Lead-acid batteries. In 1991, the B.C. Ministry of Environment began a battery collection program to provide incentives for industry to recover used lead-acid batteries. Transportation incentives for registered collectors are based on the world market price of lead and the relative distance to processing, so that if world lead prices are high, as they are now, government incentives are low. The Ministry estimates that nearly 100% of all batteries are collected, and virtually all of the lead-acid batteries are recycled. Plastic casings are washed and pelletized for plastics recycling, sulphuric acid is neutralized and/or re-used in industrial processes, and the lead is smelted and refined for use in new lead-acid batteries (60%) or other lead products (BCMWLAP 2004).

- Beverage containers. When the provincial *Litter Act* came into effect in 1970, B.C. set up a deposit–refund system for soft drink and beer containers. In 1997, the province replaced the *Litter Act* with the Beverage Container Stewardship Program Regulation, because of the many other types of beverage containers contributing to litter and being sent to landfills. Under the regulation, all brand-owners of ready-to-drink beverages (except milk, milk substitutes, liquid-meal replacements, and infant formula) were obligated to take back empty containers with a deposit–refund system, and the containers had to be either refilled or recycled. The regulation set a goal of recovering 85% of sold containers (BCMOE 2005). The regulation was later repealed and, as of October 2004, beverage containers have been included in the Recycling Regulation, which set the recovery target for beverage containers at 75%.

  Three stewardship agencies are responsible for the different types of beverage containers: Encorp Pacific (Canada) collects non-alcoholic beverage containers (57% of containers sold in 2004), Brewers Distributors Ltd. collects refillable glass bottles and aluminium cans for domestic beer, ciders, and coolers (33% in 2004), and the Liquor Distribution Branch collects wine, spirit, and non-refillable beer, cider, and cooler containers (10% in 2004) (BCP 2005). The Liquor Branch is currently in the process of turning over its container collection to the other two agencies.

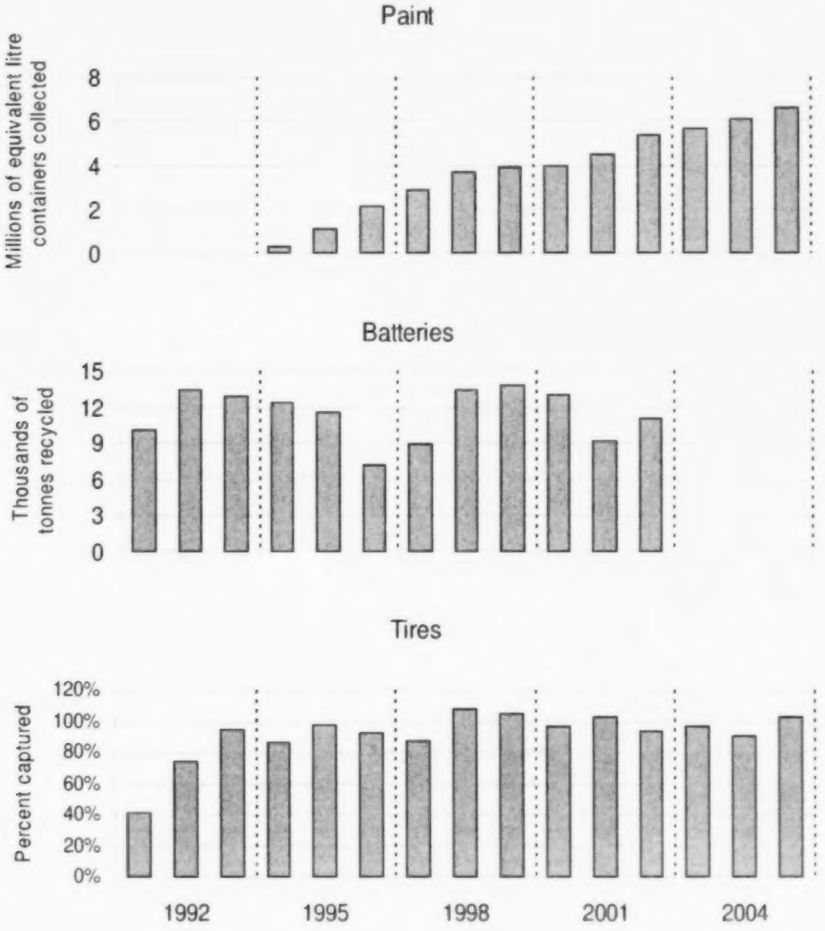
- Medications. Unused and expired medications are hazards both to human health and safety and to the environment if they are disposed of in landfills or in the sewer system. In an effort to prevent inappropriate disposal, the pharmaceutical industry voluntarily established a Medications Return Program in 1996, and in 1997, the province included the pharmaceutical industry in the Post-Consumer Residual Stewardship Program Regulation. Since October 2004, the industry has been regulated under the Recycling Regulation. The stewardship program allows consumers to return residual medications (including all prescription drugs, non-prescription medications, herbal products, mineral and vitamin supplements, and throat lozenges) to a pharmacy at no charge to the consumer. Most B.C. pharmacies participate in the program (PCPSA, undated). The medications are stored in a container at the pharmacy. When the container is full it is picked up and shipped to licensed incineration facility for safe destruction.

- Electronic products. The most recent addition to B.C.'s Recycling Regulation is for selected electronic products, including computer equipment and televisions. The Electronics Stewardship Association of British Columbia and Encorp Pacific will deliver the product stewardship program, which was initiated in August 2007 (for details see the Electronics links at *www.recycling.gov.bc.ca*). New computer equipment and televisions sold in the province will be subject to an environmental handling fee, which will pay for the cost of the program. The collected electronic products will be processed to recover raw materials, including lead, mercury, cadmium, copper, gold, glass, and plastics.

Methodology and Data

Data for seven B.C. product stewardship programs (excluding the recently launched electronic products program) were extracted from the Product Stewardship Agency reports, most of which are available under product or stewardship agency links on the Ministry of Environment's website (*www.recycling.gov.bc.ca*). Specific methodology is presented separately for each program, along with collection and recycling data (Figure 14 and Tables 9 to 15).

Figure 14. Trends in product recycling from key industry stewardship programs (paint, lead-acid batteries, tires) in B.C. (Note different quantities on *y*-axis.)



Source: See Tables 7 to 9 for sources of data for each type of product shown in this overview.

Note: The 1991 year for tires was for 9 months of records; some years tire recovery was more than 100% of tires sold because previously stockpiled tires were recycled.

Household paint, flammable liquids and gasoline, and pesticides. Paint collection began in 1994, and the number of containers (measured as the equivalent number of one-litre containers, or elc) has increased steadily, reaching 6.6 million elc in 2005 (Table 9). Note that this figure does not indicate the volume of paint collected, only the volume of containers collected.

Collection of solvents, flammable liquids, gasoline, and pesticides began in 1998. For flammable liquids and gasoline, collection has fluctuated between 71,023 and 147,688 elc, with a steady increase since 2000. For pesticides, collection has fluctuated between 16,334 and 31,968 elc, peaking in 2004.

Data on volume of product sold versus volume of product recovered are available only for 2005. In that year, 6.2% (by volume) of paint sold was recovered; 1% of flammables sold was recovered (recovered flammables included both flammable liquids and gasoline, but flammables sold did not include gasoline); and 6.1% of pesticides sold was recovered (Product Care Association 2006).

Table 9. Equivalent litre containers (elc) of household paint, flammable liquids and gasoline, and pesticides recovered.

Year	Paint collected (elc)*	Flammables collected (elc)	Pesticides collected (elc)
1994	284,000	–	–
1995	1,099,000	–	–
1996	2,111,000	–	–
1997	2,889,000	–	–
1998	3,702,000	98,928	30,850
1999	3,900,000	105,065	22,464
2000	4,000,000	71,023	16,334
2001	4,500,000	87,696	19,008
2002	5,386,993	93,170	25,056
2003	5,683,337	121,746	31,536
2004	6,120,203	139,141	31,968
2005	6,604,252	147,688	28,512

Source: Product Care Association annual reports: *www.productcare.org/BCpublications.html*.

* elc = equivalent litre container. This is a measure of the original container capacity, not the volume of contents recovered.

Tree-marking paint. Data for tree-marking paint products sold and then recovered for processing are available for 2001 to 2005. They show that 35–41% of containers sold were recovered and processed each year (Table 10). The percentage increased for the first 4 years of reporting and declined in 2005 because fewer containers were processed at one processing location on Vancouver Island (TSA 2006).

Table 10. Number of containers of tree-marking paint sold and processed.

Year	Containers sold	Containers processed	% processed
2001	481,305	170,618	35
2002	440,375	173,517	39
2003	378,066	156,111	41
2004	381,109	156,017	41
2005	418,955	146,751	35

Source: TSA 2006.

Used oil, oil filters, and oil containers. The British Columbia Used Oil Management Association (BCUOMA) reports the amount of used oil, filters, and containers collected, as well as the percentage that were recovered. In 2005 and 2006, more than 47 million litres of used oil, nearly 5 million used filters, and 1.2 million kilograms of used containers were collected (Table 11). This represents approximately 70% of the oil sold (total sales minus the amount consumed in use, which is estimated at 30.1% of the volume; Spence 2005), approximately 80% of the filters sold, and 51–57% of the containers sold. The BCUOMA does not report the amount or percentages of collected products that are subsequently recycled.

Table 11. Used oil, oil filters, and oil containers collected.

	Oil collected		Oil filters collected		Oil containers collected	
Year	(litres)	(%)[a]	(number)	(%)[b]	(kg)	(%)[b]
2003[c]	17,084,490	60	1,750,521	18	264,871	12
2004	44,119,202	72	4,721,232	82	1,055,969	42
2005	47,740,794	73	4,925,339	81	1,241,032	51
2006	47,554,996	71	4,729,007	77	1,254,001	57

[a] % litres sold minus litres consumed during use (estimated at 30.1%).

[b] % number or kg sold.

[c] 6 months.

Source: BCUOMA 2006 report (*www.usedoilrecycling.com/uploads/2006BCUOMAAnnualReport.pdf*); previous years available from B.C. Ministry of Environment internal data.

Scrap tires. Under the FIRST program, the number of scrap tires collected increased steadily from 1991–92 to 2005–06. Over the past 8 years, at least 90% of the collected tires have been converted to end-use products or fuel (Table 12). In some years, the percentage of converted tires exceeded 100% because processors recycled tires stockpiled from previous years.

Table 12. Scrap tires collected and converted to end-use products.

Year	Scrap tires collected (tonnes)	Scrap tires converted to end-use products and fuel (tonnes)	Tires converted as % of collected*
1991–92	11,134	4,526	41
1992–93	17,059	12,546	74
1993–94	20,683	19,590	95
1994–95	22,353	19,353	87
1995–96	20,952	20,442	98
1996–97	26,584	24,673	93
1997–98	25,338	22,107	87
1998–99	25,016	27,041	108
1999–00	27,257	28,598	105
2000–01	28,074	27,047	96
2001–02	27,953	28,660	103
2002–03	28,881	26,867	93
2003–04	29,387	28,346	97
2004–05	31,618	28,679	91
2005–06	31,836	32,573	102

Source: Annual Performance Statistics, Min of Environment, FIRST Program, Update to Feb 2006.

* Percentages exceed 100% in some years when processors converted tires stockpiled from previous years.

Lead-acid batteries. Data are available from the beginning of the B.C. Lead-Acid Battery Collection Program in 1991 to the end of the 2002–03 fiscal year. They show that between 7,000 and nearly 14,000 tonnes of batteries are recycled each year (Table 13). The peak was in 1999–2000, when 13,744 tonnes of batteries were recycled.

The program aims to recover at least 98% of all used lead-acid batteries in BC annually (BCMWLAP 2004). Although the Ministry of Environment Hazardous Waste manifest system tracks lead-acid battery shipments weighing over 1000 kg, data are not collected on battery sales, so it is not possible to determine the actual percentage of recovery. BCMWLAP (2004) estimated that nearly 100% of batteries are recovered when market conditions are ideal. For example, lead prices are currently high enough to provide market incentives to collect batteries and process them to extract the lead for re-use. The fact that municipalities and regional districts are not detecting inappropriate disposal of batteries in land-fills supports the assumption that there is a high level of recovery. The federal government closely monitors the risk of illegal export to Asian markets.

Table 13. Lead-acid batteries recycled.

Year	Batteries recycled (tonnes)
1991–92*	10,137
1992–93	13,406
1993–94	12,850
1994–95	12,398
1995–96	11,502
1996–97	7,168
1997–98	8,950
1998–99	13,382
1999–00	13,744
2000–01	12,943
2001–02	9,188
2002–03	10,953

Source: MWLAP 2004.

* 10 months

Beverage containers. In this indicator, the data from the three industry stewards (Encorp Pacific, Liquor Distribution Branch, and Brewers Distributors Ltd.) have been amalgamated; comparable data from all three have been available only since 1998. From 2001 to 2005, the number of containers sold increased from 1.5 million to 1.8 million, and 81 to 84% of these containers were recovered each year (Table 14). The decrease in 2004 from the previous year's recovery rate is attributed to several factors, including difficulties in finding additional depot sites in Vancouver because of zoning issues; increased sales of bottled water in <1-litre containers, which are sold and distributed in different ways than juices and soft drinks; and growth in the number of private liquor stores whose large start-up inventories are counted as sales even though they have not yet been sold to the public (BCP 2005).

Table 14. Beverage containers* sold and recovered in B.C. (includes wine, spirits, beer, cider, coolers, and non-alcoholic beverage containers).

Year*	Number sold	Number recovered	% recovered
2001	1,545,837,587	1,252,168,334	81
2002	1,602,339,106	1,341,842,780	84
2003	1,688,947,095	1,415,077,851	84
2004	1,771,286,403	1,440,601,233	81
2005	1,824,050,525	1,476,102,022	81

Source: Beverage Container Stewardship Program annual reports.

*Encorp Pacific (Canada) reports by calendar year (1 Jan.–31 Dec.), but Liquor Distribution Branch and Brewers Distributors Ltd. report year as 1 April–31 March, thus, for example in 2001, their data are for 2001–02.

Medications. The amount of pharmaceuticals collected by pharmacies has increased since the program began in 1996. There have been fluctuations over the years as reporting periods changed and when a new container system was implemented in 2002. In 2005, more than 18,000 kg of medications were collected (Table 15). This weight includes the packaging of liquid medications and non-liquid medications (unless plastic recycling services are available in the participating pharmacy's community). The number of participating pharmacies has increased from about 650 at the beginning of the program to more than 850 in 2007. Although final numbers are not available, the Post-Consumer Pharmaceutical Stewardship Association reports that the number of collected containers and weight of medications was higher in 2006 than in 2005, and they expect further growth by as much as 25% in 2007 (PCPSA 2007).

Table 15. Residual medications collected and the number of participating pharmacies in B.C.

Year	Medications collected (kg)	Number of pharmacies
1996-98[a]	6,703	–
1998-99[b]	10,105	643
1999-00[b]	11,479	650
2000[c]	4,490	550
2001	10,500	680
2002[d]	18,881	719
2003[d]	10,094	734
2004	15,503	802
2005	18,012	845

Source: Medications Return Program Annual Reports, 1998–2005.

[a] = 18 months reporting period.

[b] = 12 months.

[c] = 9 months.

[d] Due to change to UN-approved collection containers, medications that would normally have been reported for 2003 were included in 2002 results.

Interpretation

The seven established product stewardship programs in B.C. have a variety of data collection and reporting formats, making it difficult to assess the success of some programs and to compare results. If there is no tracking of total sales of a product or another similar measure, it is not possible to determine the significance of the number, volume, or weight of recovered and/or recycled product. In addition, few of the industry stewardship programs report targets for the amount or percentage of end-of-life product they aim to recover. Nevertheless, the data in this indicator suggest that a large volume of hazardous and non-biodegradable products are diverted from landfills in B.C. each year.

Despite the reporting challenges, British Columbia has been a leader in many of the industry stewardship programs that are currently in place in the province. For example, in 1970, B.C. was the first jurisdiction in North America to introduce a mandatory deposit–refund system for beverage containers, and the Lead-Acid Battery Program introduced in 1991 was the first of its type in Canada (BCMOE 2006b). New product categories continue to be considered for addition to the group of programs already underway.

At the national level, the Canadian Council of Ministers of the Environment (CCME) has an active task group examining issues of extended producer responsibility. The group's mandate is to guide extended producer responsibility and product stewardship programs. Its first priority is to work on designing packaging that takes environmental impact into account (Marbeck Resource Consultants 2007).

Economy and the Environment

7. Key Indicator: Intensity of conventional energy use in economic activity in B.C.

Economic activity uses energy and all energy production, transmission, and use has some type of environmental impact. For example, burning fossil fuels emits air pollutants and greenhouse gases; large hydroelectric dams flood large areas of land.

This is a pressure indicator. It shows how much energy from conventional sources is consumed per unit of the province's gross domestic product (GDP). The GDP is a measure of the total value of goods and services produced by the province's economy.

Conventional energy sources include all of the sources for which data are available, including fossil fuels and large hydroelectric facilities. Ideally, all types of energy resources should be accounted for in an energy intensity indicator. However, limited data are available on biomass energy sources, small-scale hydroelectric, and other small or "alternative" energy sources.

Improvements in energy efficiency and a move toward greater use of solar or wind energy would cause energy intensity to decrease. This equates to lower environmental impact per unit of economic activity (GDP).

Methodology and Data

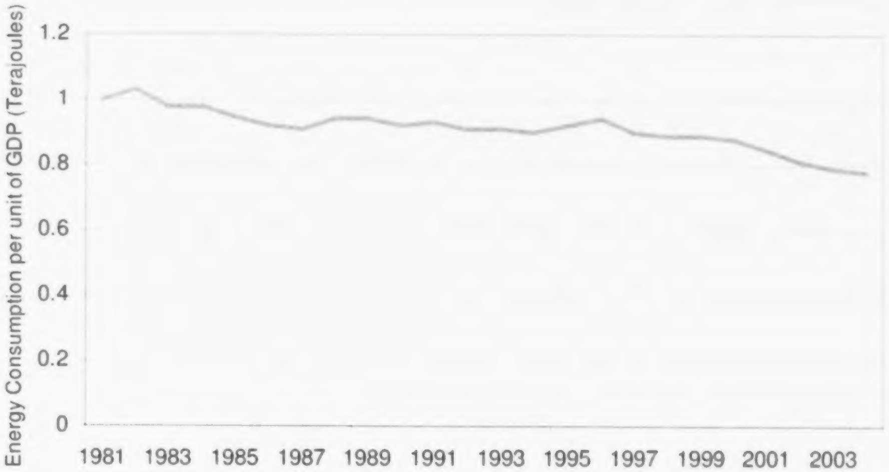
Energy intensity is calculated as a ratio of economy-wide conventional energy consumption (in terajoules) to the GDP. The GDP values were obtained from BC Stats (2007a) and are measured in constant dollars (i.e., GDP values are adjusted for inflation using 1997 as the base year), which allows different years to be compared.

The data are presented both as a ratio of terajoules per dollar of GDP and as an index to make the percentage change in energy intensity for each year readily apparent (Table 16, Figure 15). The index for each year was calculated by dividing the energy consumption to GDP ratio for that year by the energy consumption to GDP ratio for 1981 (the base year for the index).

For this indicator, conventional energy consumption includes the consumption of petroleum, natural gas, coal, and coke, and hydroelectricity. It includes energy used by final consumers for residential, agricultural, commercial, industrial, and transportation purposes, as well as energy used in transforming one energy form to another (e.g., coal burning to produce electricity), and energy used by suppliers in providing energy to the market (e.g., pipeline fuel) (NRC 2006).

Results for years before 2000 in the current report are not exactly as reported in the previous Environmental Trends (BCMWLAP 2002). GDP numbers have changed because they are now based on a 1997 base year, rather than a base year of 1992, as in previous reporting. Also, as new information is obtained each year there may be changes in definitions, industry coverage (e.g., steam was not included in 2002), and methodology. Historical time series data is updated to reflect current methods and make it possible to compare past and present results.

Figure 15. Consumption of conventional energy in B.C. per unit of Gross Domestic Product (GDP).



Sources: Energy data, Statistics Canada; GDP data, BC Stats 2007.

Table 16. Consumption of energy in B.C. from conventional[a] sources and intensity of use from conventional sources.

	Energy consumption from each source (in terajoules)								
Year	Coal and coke	Natural gas	Primary electricity hydro	Steam[b]	Petroleum products	Total [c]	GDP (millions of 1997 constant dollars)	Total energy consumption (terajoules/ GDP[d])	Intensity of energy use (index = 1.00 in 1981)
1981	4,753	165,796	140,079	0	360,898	671,526	79,745	8.4	1.00
1982	2,909	178,231	142,064	0	323,603	646,807	74,877	8.6	1.03
1983	3,267	186,029	148,576	0	284,007	621,879	75,349	8.2	0.98
1984	3,549	190,670	151,755	0	279,295	625,269	75,930	8.2	0.98
1985	3,332	207,001	161,100	13	275,126	646,572	81,203	8.0	0.95
1986	6,253	187,204	162,785	0	275,899	632,141	81,355	7.8	0.92
1987	3,821	205,335	167,239	0	289,055	665,450	86,373	7.7	0.91
1988	4,686	225,968	178,195	0	310,921	719,770	91,395	7.9	0.94
1989	4,795	237,551	181,029	0	325,890	749,265	94,400	7.9	0.94
1990	4,104	229,775	188,313	0	318,699	740,891	95,722	7.7	0.92
1991	5,164	237,464	189,829	0	315,719	748,176	95,897	7.8	0.93
1992	7,761	241,132	192,056	0	312,920	753,869	98,373	7.7	0.91
1993	7,684	264,011	198,842	0	316,797	787,334	102,770	7.7	0.91
1994	7,919	269,252	197,814	59	324,437	799,481	105,669	7.6	0.90
1995	8,135	282,558	205,864	15	343,761	840,333	108,194	7.8	0.92
1996	7,930	308,381	207,558	17	357,214	881,100	110,857	7.9	0.94
1997	6,793	290,097	203,071	9	370,072	870,042	114,383	7.6	0.90
1998	5,635	281,971	207,124	0	372,447	867,177	115,883	7.5	0.89
1999	6,740	288,553	212,330	2,816	384,043	894,482	119,604	7.5	0.89
2000	9,384	307,298	219,385	2,865	387,340	926,272	125,145	7.4	0.88
2001 [e]	10,080	293,859	211,549	2,680	381,986	900,154	125,924	7.1	0.85
2002 [e]	10,776	280,420	212,953	201	381,516	885,866	130,445	6.8	0.81
2003	11,473	266,982	214,635	297	394,262	887,649	134,131	6.6	0.79
2004	14,263	265,047	222,096	2,031	416,615	920,052	140,263	6.6	0.78

Sources: Energy data, Statistics Canada (CANSIM - Canadian Socio-economic Information Database); GDP data, BC Stats 2007.

[a] Conventional energy sources include fossil fuels and hydroelectric sources.

[b] Known steam sales of large producers only.

[c] Discrepancies between row totals and total shown in this column are due to rounding.

[d] Conventional energy intensity is calculated as the ratio of total conventional energy consumption to GDP.

[e] Energy consumption data for 2001 and 2002 was incomplete, as it was suppressed to meet the confidentiality requirements of the *Statistics Act*. Gaps were filled by extrapolating the information.

Interpretation

During the nearly 25 years for which this indicator has been calculated, energy intensity has decreased steadily although total energy consumption has continually increased (Figure 15). Reductions in energy intensity are due to a combination of factors, including a shift in the structure of the economy toward less energy-intensive sectors (e.g., knowledge-based, service, tourism), increased energy efficiency of existing activities, and a larger amount of energy consumption from alternative energy sources.

A concern regarding the reliability of this indicator is that some factors have the potential to change energy intensity estimates even when there has been no change in the amount of energy consumed to produce goods and services. For example, energy consumption is affected by weather conditions; therefore, with all other factors constant, changes in weather conditions alone could affect economy-wide energy intensity estimates, even though there has been no change in the production of goods and services. Another factor would be the production of non-market goods and services that are not included in the GDP. Since the energy consumed to produce them is included in the energy consumption estimate, the calculations could somewhat overestimate the energy intensity.

Energy intensity calculations are more reliable when they are done at a sectoral level, rather than at the economy-wide level, because it is easier to account for factors that affect energy intensity estimates. This results in a more accurate link between the estimates of sectoral energy consumption and the value of goods and services produced using that energy and makes it possible to draw more meaningful conclusions about energy use in the sector. Using the transportation sector as an example, energy intensity would change due to factors such as variations in the proportions of vehicle types in use, energy efficiency of the vehicles, and energy sources.

8. Secondary Indicator: Trends in greenhouse gas intensity in B.C.

Greenhouse gas intensity is the ratio of greenhouse gas (GHG) emissions to economic output (measured as Gross Domestic Product or GDP). The GDP is the total dollar value of all goods and services made and purchased within one year by individuals and households, government, and businesses.

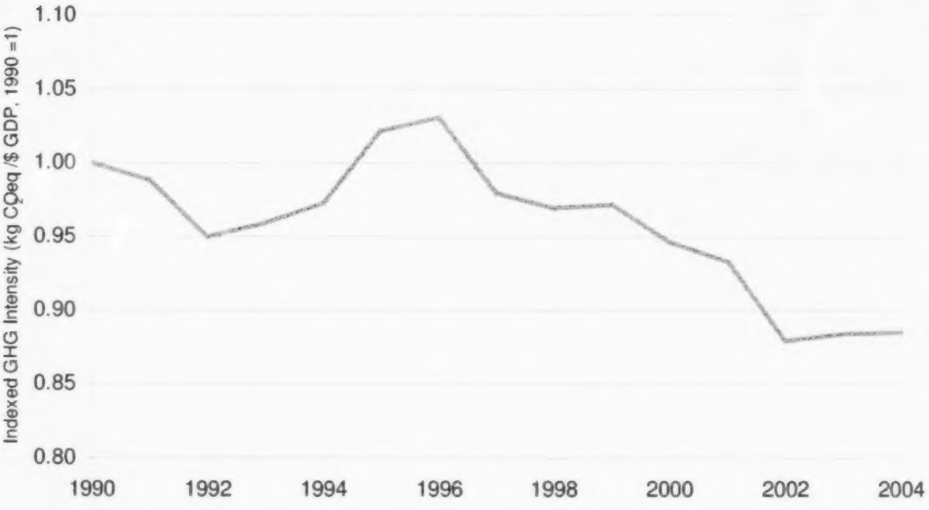
As long as economic output is constant or increasing, GHG intensity decreases with increases in efficiency and use of renewable energy. Factors that decrease (thus improve) greenhouse gas intensity include:

- Technological changes that improve the overall energy efficiency of processes.
- Increased use of renewable energy, such as wind power, solar energy, and hydroelectric or other water-power sources.
- Substitution of natural gas for coal and oil as an energy source.
- Use of fuels with a higher biofuel content, such as ethanol.

Methodology and Data

Greenhouse gas intensity (Figure 16 and Table 17) is calculated by dividing the amount of greenhouse gases produced in tonnes (Environment Canada 2006) by the GDP (BC Stats 2007; dollar values converted to 1997 equivalents so years could be compared). Greenhouse gas intensity calculations include all greenhouse gases, which are converted into CO_2 equivalents (CO_2e). In Canada in 2004, carbon dioxide contributed the largest share of greenhouse gas emissions at 78%, methane accounted for 15%, nitrous oxide accounted for 6%, and miscellaneous other gases contributed the remaining 1% (Environment Canada 2006).

Figure 16. Trends in greenhouse gas intensity in B.C., 1990–2004, as the ratio of greenhouse gas (GHG) emissions to gross domestic product (GDP) relative to a 1990 baseline.



Sources: GHG data, Environment Canada 2006; GDP, BC Stats 2007.

Table 17. Trends in greenhouse gas intensity in B.C., 1990–2004, shown as the ratio of greenhouse gas (GHG) emissions to gross domestic product (GDP).

Year	GHG (thousand tonnes of CO_2e)	GDP (chained $1997 million)	GHG intensity (tonnes CO_2e per $ of 1997)	GHG intensity (kg CO_2e per $ of 1997)
1990	51500	95,722	0.00054	0.54
1991	51000	95,897	0.00053	0.53
1992	50300	98,373	0.00051	0.51
1993	53000	102,770	0.00052	0.52
1994	55300	105,669	0.00052	0.52
1995	59500	108,194	0.00055	0.55
1996	61500	110,857	0.00055	0.55
1997	60300	114,383	0.00053	0.53
1998	60400	115,883	0.00052	0.52
1999	62500	119,604	0.00052	0.52
2000	63700	125,145	0.00051	0.51
2001	63200	125,924	0.00050	0.50
2002	61700	130,445	0.00047	0.47
2003	63800	134,131	0.00048	0.48
2004	66800	140,263	0.00048	0.48

Sources: GHG data, Environment Canada 2006; GDP, BC Stats 2007.

For Canada, from 1990 to 2004, GHG emissions per unit of GDP decreased by 13.8% while the total GHG emissions rose by approximately 27%. The rate of GHG emissions rose faster than the population (which grew by 15%) during the 14-year period and was about equal to the increase in energy use. Because the growth in total emissions was less than the 47% growth in GDP between 1990 and 2004, GHG intensity decreased by about 14% over the period (Environment Canada 2006).

Interpretation

Intensity-based targets for GHGs means that the environmental impact is calculated relative to the economic output of the country. Being able to produce lower emissions per barrel of oil accomplishes a target of decreasing greenhouse gas intensity, even though a growing economy may mean that more barrels of oil are used. Intensity targets are more palatable for the most affected industries, because it allows economic growth to continue. However, because intensity targets are tied to economic growth, total greenhouse gas emissions can continue to rise as long as they decrease relative to economic growth.

Calculating GHG intensity can be quite complex. A recent study found that for many Canadian manufacturing sectors, trade with the United States increased their greenhouse gas intensity

(Norman et al. 2007). This is because resource and manufacturing sectors in the US are more energy- and GHG-intensive than in Canada, due to a greater reliance in the US on fossil fuels and on electricity generated by fossil fuels.

Supplementary Information: Economic value versus environmental value

Currently, the Gross Domestic Product (GDP), which estimates the value of goods and services exchanged in the marketplace, is a widely used, primary measure of economic activity. The GDP is also widely used as a proxy measure of economic health, of human well-being or of social progress. As the GDP was not intended for this use, it can be both inadequate and misleading when used for these purposes. For example, expenditures as a result of crime, natural disasters, or environmental pollution are counted in the GDP, so a local economy can appear to benefit from polluting activities and clean-up costs. Furthermore, the GDP does not include non-monetary values or ways of measuring environmental condition, so it ignores the depletion or degradation of natural resources. It also does not value the non-market economy of households, communities, and volunteer work.

Worldwide, governments have begun to recognize the importance of including a valuation of natural or environmental capital in measures of national economic welfare. Natural capital is the stock of renewable and nonrenewable natural resources, including water, soil, air, living organisms, minerals, and other environmental assets. These provide "ecosystem services" such as water purification, waste treatment, nutrient cycling, oxygen production, climate regulation, flood protection, erosion control, soil formation, and aesthetic enjoyment (MEA 2005). Although ecosystem services support life on the planet, their value is poorly understood and traditionally ignored in decision-making processes that use the economic value of a good or service as the basis for comparisons (Emerton and Bos 2004).

Since the 1990s, the concept of a "green GDP" that adjusts the traditional GDP measure to take into account environmental costs and the value of ecosystem goods and services has attracted the interest of governments around the world (Perman et al., 2003). Economists have developed a variety of methods for measuring the contribution of ecosystem services to the economy and have been exploring how to integrate these values into the systems of national accounts. The "green GDP" concept also has been taken up by businesses that see bottom-line benefits to behaving in socially and environmentally responsible ways. Corporate social responsibility (CSR) has become attractive as a concept and is backed up by ranking systems that judge companies on such criteria as human rights, environmental impacts, and contributions to the well-being of community and society (e.g., see in Canada, Brearton et al. 2005).

It is exceedingly difficult to measure the benefits provided by the environment and there is no consensus on how to calculate such a "green GDP" or whether it should be attempted at all (UN European Commission et al. 2003). Several frameworks for measuring economic well-being and sustainability have been developed over the past 30 years. Although each approach has strengths, there is no agreement on a single model that combines measures of economic well-being (in monetary terms) and quality of life indicators (in non-monetary terms).

Numerous attempts have been made to value the benefits to the financial economy and to human health and well-being from ecosystem services. Among the more prominent of these efforts are:

- **Environment and Sustainable Development Indicators (ESDI) Initiative.** In 2000, the National Roundtable on the Environment and the Economy, in partnership with Environment Canada and Statistics Canada, produced a small set of indicators to track natural capital (i.e., air quality, freshwater quality, greenhouse gas emissions, forest cover, and extent of wetlands), and human capital (i.e., educational attainment). The national roundtable also recommended that the government expand the system of National Accounts and improve the national environmental information systems.
- **Genuine Progress Index (GPI).** The GPI was proposed in 1994. It broadens the conventional accounting framework to include economic contributions of families, community, and natural habitat. It measures factors that contribute to a decline in the well-being of society, and quantifies their cost to society. It also takes into account more than 20 aspects of people's lives that the GDP does not and integrates them into a composite measure so the benefits of economic activity can be weighed against the costs. This is intended to provide citizens and policy-makers with a more accurate measure of the overall health of the economy, and of how national conditions change over time (Cobb et al. 1995). See *www.rprogress.org/newprograms/sustIndi/gpi/index.shtml.*

  In Canada, the non-profit research group GPI Atlantic has developed a Genuine Progress Index for Nova Scotia, and the Pembina Institute has completed a major project to develop a GPI for Alberta (Taylor 2006).

- **Environmental Sustainability Index (ESI)** is an initiative of the Yale Center for Environmental Law and Policy and the Center for International Earth Science Information Network of Columbia University. The ESI benchmarks the ability of nations to protect the environment over the next several decades. It does so by integrating 76 data sets (tracking natural resource endowments, past and present pollution levels, environmental management efforts, and a society's capacity to improve its environmental performance) into 21 indicators. See *http://sedac.ciesin.columbia.edu/es/esi/.*
- **Environmental Performance Index (EPI).** Another initiative from the same source as the ESI (above), the EPI provides benchmarks for current national pollution control and natural resource management results. The issue-by-issue and aggregate rankings facilitate between-country comparisons both globally and within relevant peer groups. Environmental health and ecosystem vitality are gauged using indicators of environmental health, air quality, water resources, biodiversity and habitat, productive natural resources, and sustainable energy. See *www.yale.edu/epi/.*
- **Adjusted Net Savings (or Genuine Savings).** An initiative of the World Bank, adjusted net savings measure the "true" rate of savings in an economy after taking into account investments in human capital (i.e., education), depletion of natural resources, and damage caused by pollution. The World Bank has been publishing estimates of adjusted net savings since 1999 for more than 100 countries. See: *http://go.worldbank.org/EPMTVTZOM0.*

WHAT IS HAPPENING IN THE ENVIRONMENT?

In 2007, more than 4.6 million people lived in British Columbia. According to the most recent estimates, the B.C. population is expected to grow to 5.5 million people in 2030. As the number of people living in the province grows, pressure on the environment inevitably increases. Loss of natural habitat to development and agriculture, increasing demand for water, lumber and other resources, the release of pollutants, and production of waste all have environmental impacts.

The most rapid growth rates in B.C. have taken place in Metro Vancouver (formerly the Greater Vancouver Regional District), with the population density nearly doubling between 1976 and 2006. The Capital Regional District (Victoria), and the Nanaimo and Central Okanagan regional districts are the next fastest growing regions. Population patterns reflect both the continual expansion of urban centres and a shift in the economic and industrial activity within the province. In a few rural regional districts, such as Skeena-Queen Charlotte, the population density has decreased slightly, probably linked to the downturn in natural resource industries.

In the Lower Mainland, policies at the regional level and provincial level (i.e., the Agricultural Land Reserve) appear to have restrained suburban sprawl and slowed the loss of rural land. Between 1991 and 2001 the population of the region increased by 25%, yet the area of land converted to urban uses only increased about 2%.

The Agricultural Land Reserve (ALR) was put in place at the provincial level to protect agricultural land in 1974. Since then the total area, province-wide, has increased slightly (1%). Most of the movement of land in and out of the ALR has been "secondary capability land," meaning that it is suitable mainly for grazing or forage crops and is not prime agricultural land. The loss of prime agricultural land in the ALR is most noticeable in the Okanagan and South Coast where the population is highest and the demand for land for development is the greatest. However, the loss of agricultural land undoubtedly would have been higher if the ALR did not exist. For example, according to Smart Growth BC, although the population in Metro Vancouver has consistently increased since the mid-1970s, the region's annual rate of ALR loss has declined steadily since 1983. They estimate that without the ALR, Metro Vancouver might have converted as much as 7000 additional hectares to urban development (Smart Growth BC 2005).

As the level of sewage treatment increases, fewer contaminants are released into the environment. The proportion of the B.C. population with primary sewage treatment (35%), secondary treatment (56%), and tertiary treatment (8%) has remained the same since 1999. These proportion are not expected to change until there are major upgrades to treatment plants, as happened with the Annacis and Lulu Island facilities in 1999. The importance of providing adequate sewage treatment is shown by the large area of shellfish beds closed due to contamination with fecal coliform bacteria. The area increased by about 40,000 hectares from 1990 to 2006, primarily as a result of increasing population and associated sewage discharges. Other sources of fecal contamination include poorly placed or maintained septic tanks, agricultural and urban runoff, and discharge from marine vessels.

Pressure on the environment also comes from disposal of waste. B.C. now has eight industry-led product stewardship programs that divert recyclable materials and hazardous materials from landfills. Seven established programs cover used oil, scrap tires, lead-acid batteries, beverage containers, medications, tree-marking and household paint, solvents and pesticides. The newest is the Electronic Products Waste Program, set up in 2007. Records from the established programs show that a large volume of hazardous and non-biodegradable products have been diverted from landfills. Recycling and waste diversion programs have succeeded in keeping the total amount of disposed waste in B.C. today to about the same total volume as in 1990, despite the increasing population. Although the amount of waste disposed per person is still lower than it was in 1990, it has not improved over the last decade, despite recycling and disposal programs.

Since 1981, the energy intensity for economic activity in B.C. (energy consumed per unit of gross domestic product or GDP) has decreased, even though total energy consumption has continued to increase. This equates to a lower environmental impact per unit of economic activity, as it takes less energy to accomplish the same activity. Reductions in energy intensity are due to a combination of factors, including increased energy efficiency, a shift toward less energy-intensive activities (e.g., knowledge-based, service, tourism), and the use of more energy from alternative energy sources. Similar factors led to a reduction in greenhouse gas (GHG) intensity (the ratio of GHG emissions to economic output or GDP) in B.C. between 1990 and 2004.

WHAT IS BEING DONE ABOUT IT?

The negative impacts of population growth can be mitigated by strong growth-management policies and strategies, as well as by adoption of technology and participation in initiatives that reduce consumption or emissions to the environment.

Policies that reduce the impact of urban growth on the natural environment include limiting growth outside of urban core areas, increasing densification of these core areas, providing mass transit, supplying incentives for using environmentally sound technology, and encouraging low-impact development infrastructure and green building strategies. The impact of such efforts are shown as trends in the indicators reported in this paper. For example "smart growth" strategies appear to be slowing the rate at which land is converted to urban uses in Metro Vancouver. The Agricultural Land Reserve has also slowed the loss of prime agricultural land in Metro Vancouver, although losses still occur in the South Coast region as a whole, and in the Okanagan.

Another indication of effort to reduce human impacts is that the proportion of the province's population served by secondary sewage treatment facilities increased substantially between 1983 and 1999, reflecting a significant investment in environmental infrastructure. Since 1999, however, there have been no significant changes in the proportion of the population served by higher levels of wastewater treatment.

Programs to reduce the amount of solid waste disposed of in landfills—including industry-led product stewardship and recycling programs—have been in place for more than 15 years in B.C. They have succeeded in keeping the amount of disposed waste per person lower than it was in 1990. However, the initial downward trend over the 1990s in the amount of waste disposed per person annually has not continued, and over the last 10 years there has been essentially no change in the waste disposed per person. Despite an increasing population, the recycling and waste diversion programs did succeed in keeping the total amount of disposed waste today to essentially the same total volume as in 1990. Also, a range of hazardous and non-biodegradable items have been diverted from landfills and either recycled or disposed of appropriately.

Some other important initiatives and programs aimed at protecting the province's environment and managing the impacts of human population and economic activities are described below.

Environmental Farm Plans and Beneficial Management Practices

In 2004, the governments of Canada and B.C., in cooperation with industry, initiated a program to help B.C. agricultural producers develop and implement Environmental Farm Plans (EFPs). Environmental farm planning is a voluntary process that producers can use to identify environmental strengths and potential risks on their farms. The current program—funded under the Canada-British Columbia Agriculture Policy Framework Agreement—ends in March 2008. In British Columbia, the program is delivered by the B.C. Agriculture Council.

Although the EFP program is open to all farms in the province, its primary target is commercial farms. According to Stats Canada (2001) there were about 4850 commercial farms (defined as farms with more than $50K in farm gate sales) in B.C. in 2000.

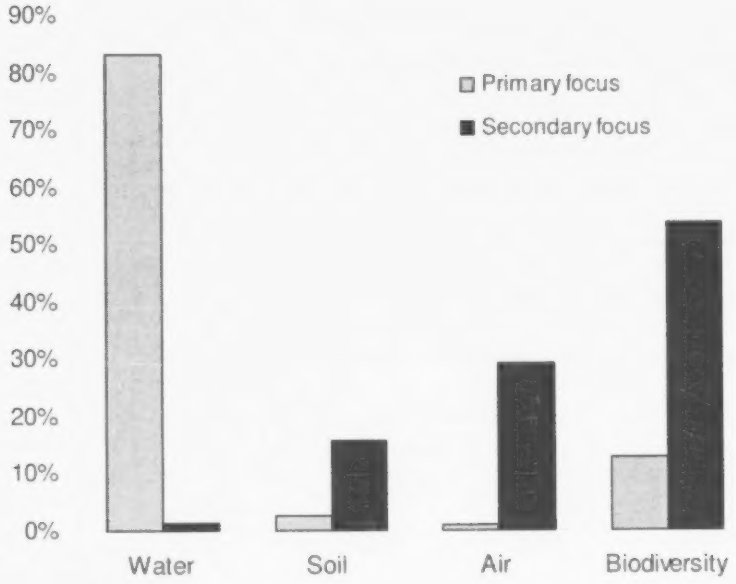
Between 2004 and 2006, a total of 1302 EFPs were completed (BCAC 2007), well above the target of 800 EFPs set by the B.C. Ministry of Agriculture and Lands.

A beneficial management practice (BMP) is a farm practice that enhances environmental benefits and/or reduces environmental risk. Producers who have completed an EFP are eligible for cost-shared incentives to help them implement specific BMPs related to the Agriculture Policy Framework (Agriculture and Agri-Food Canada 2005) priorities of soil, water, air, and biodiversity. BMPs may be primarily directed at one priority, but most provide additional benefits to one or more other priority areas (G. Hughes-Games, Provincial Soil Specialist, B.C. Ministry of Agriculture and Lands, Abbotsford, pers. comm.).

Most (80% or 367 projects) of the 441 BMP projects implemented since the program's inception in 2004 aimed at protecting water quality or quantity (Figure 17). Of these, just under half dealt with water quantity, primarily irrigation management. The rest of the projects (74) were directed at biodiversity, soil, and air priorities. Most projects (292) also had secondary benefits for biodiversity, soil, and air.

Biodiversity projects funded as of December 2006 included invasive species control (2 projects), wildlife habitat enhancement (5 projects), and preventing wildlife damage (50 projects). Projects focussing on soil included shelterbelt establishment (10 projects) and soil erosion control planning (2 projects). BMPs that addressed air quality concerns (contaminants, dusts, and particulates) included manure treatment (4 projects) and manure land application (1 project).

Figure 17. The primary and secondary focus of Beneficial Management Practice projects funded 2004 to 2006 under the Agriculture Policy Framework's four strategic priorities of water, soil, air, and biodiversity.



Source: BCAC 2007.

Collaborative Management of Marine Fisheries

Worldwide, there is a movement toward collaborative management of fisheries by multiple stakeholders. Such fisheries tend to have healthier stocks, can be more profitable, have lower levels of resource conflicts, and provide a wider array of social and economic benefits to local communities (e.g., Pearce and McRae 2004; Wiber et al. 2004). Therefore, the number of fisheries managed through a collaborative decision-making process has been proposed as a measure of progress in managing fisheries resources sustainably (e.g., BCMOE 2007).

There are many stakeholders in B.C. fisheries, including Canadian federal and provincial agencies, First Nations, and nongovernmental groups representing the fishing industry and other resource users. The management of Pacific marine fisheries falls under federal jurisdiction (Fisheries and Oceans Canada), but once harvested, the resource is largely under provincial jurisdiction. The province is a partner in federal management of marine fisheries. Because many B.C. fisheries (e.g., tuna, halibut, salmon, hake, and sardines) have transboundary stocks, US agencies are also partners in managing the fisheries.

The collaborative management process involves advisory committee meetings and industry consultations, and ongoing interactions with industry and stakeholder groups to address issues and challenges in the management of a fishery. A key product of such collaborative efforts is an Integrated Fisheries Management Plan as required by Fisheries and Oceans Canada. These plans incorporate management measures and activities related to a specific fishery for a given year. They are created for important fisheries such as tuna, salmon, groundfish, and prawn and shrimp caught by trap.

Several commercial and recreational fisheries in B.C. are in various stages of evolution toward management through collaborative decision-making processes. Although the hake, herring, and tuna fisheries (see Table 18) are the most advanced, there is a high degree of collaboration among participants in some other fisheries, including those for Strait of Georgia rockfish and lingcod, and for sardines.

Table 18. Summary of key Pacific fisheries under collaborative management.

Fishery	Fishing method	Products	Advisory Processes / Partners	Wholesale value
Tuna	Hook and line	Albacore tuna is available fresh, frozen-at-sea (whole fish, steaks and loins), hot and cold smoked, and canned. Markets include Canada, US, EU, and Japan.	1. Canadian Highly Migratory Species Foundation 2. BC Tuna Fishermen's Association 3. Canadian Advisors to DFO on International/Bilateral Issues 4. Integrated Tuna Advisory Board	$30 M (2005)
Herring (spawn-on-kelp; roe herring and other uses)	Gillnets and seine nets	Herring roe/eggs packed in brine. Market for herring roe is primarily in Japan.	Co-managed through three main advisory processes: 1. Herring Industry Advisory Board 2. Integrated Herring Harvest Planning Committee 3. Spawn on Kelp Operators Association	Roe herring $78.7 M (2005) Total herring $85.8 M (2005)
Hake	Groundfish trawl	Pacific hake is available frozen-at-sea and as surimi. Markets include EU, Asia, Russia, and US.	Two main advisory groups: 1. Groundfish Trawl Advisory Committee 2. In-Season Advisory Committee	$58.4 M (2005)
Rockfish and Lingcod	Hook and line	Live, fresh, and frozen products. Markets are primarily Canada and US.	One main governments / stakeholder advisory group: 1. DFO Inshore Rockfish/Lingcod Recovery Strategy Other bodies that are consulted on management measures 2. Sport Fish Advisory Board 3. Groundfish Hook & Line Committee	All rockfish $40 M (2005) All lingcod $10.2 M (2005)

Sources: Oceans and Marine Fisheries Division, B.C. Ministry of Environment; Wholesale value: BCMOE 2006c.

Forestry Certification Initiatives

Certification of products provides an incentive to industries to operate sustainably by developing standards and monitoring programs that can be used by consumers who want to support environmentally responsible industries. Third-party certification programs to identify and label forest products that originate in sustainably managed forests began in the 1990s and have been expanding since then. Programs exist at the national and international levels and have spread globally.

In Canada, at least four voluntary programs certify forests according to a set of environmental and social standards. Producers and manufacturers along the supply chain also can be certified to ensure that the final product bearing the logo originated from a certified forest. Programs include:

- **The Forest Stewardship Council.** An international system covering forest management practices and the tracking and labelling of certified products and paper products with recycled content.
- **The Sustainable Forestry Initiative® Program.** A sustainable forest management standard that targets large industrial operations in Canada and the United States.
- **The Canadian Standards Association.** The CSA covers operations in Canada, setting national standards for sustainable forest management and for tracking and labelling of certified material.
- **The Program for the Endorsement of Forest Certification Schemes.** A global umbrella organization for mutual recognition of national products that meet international forest certification standards.

For more information about forestry certification and the details of each certification system, see *www.metafore.org/index.php?p=Introduction_to_Certification_Programs&s=167.*

The most rapid growth rates in B.C. have taken place in Metro Vancouver (formerly the Greater Vancouver Regional District), with the population density nearly doubling between 1976 and

WHAT YOU CAN DO

The actions of individuals count, whether it is a positive or negative contribution. For example, more than half of the oil pollution in the world's oceans comes from land-based runoff entering storm drains and streams that empty into the ocean (Smithsonian Institution 1995). Much of this is oil from vehicles that drip oil on road surfaces—the oily road runoff from a city of 5 million people can contribute as much oil to the marine environment as one large tanker spill.

British Columbians can reduce their impact on the environment and participate in programs to protect it in many ways:

- Drive less: walk, take public transit, join a car pool, ride a bicycle, or buy a fuel-efficient vehicle.

- Reduce consumption and disposal of unnecessary goods.
- Recycle materials and reduce waste. See the RCBC Recycling Hotline for recycling information and locations in your community *www.rcbc.bc.ca/services/recycling_hotline.htm* or call 1-800-667-4321 (Lower Mainland: 604-732-9253
- Get involved in local stewardship projects. Seek out community groups and get involved, or help form a group. Stewardship Centre for British Columbia (*www.stewardshipcentre.bc.ca/stewardshipcanada/home/scnBCIndex.asp*).

Support "Green" Businesses: Consumers can choose to support businesses that offer products or services with reduced environmental impacts, for example, by buying locally grown food. Also look for certification initiatives, such as:

- Independent forestry certification programs are described and compared at (*www.metafore.org/index*).
- Wild fisheries certification by the Marine Stewardship Council (MSC). The B.C. Salmon Marketing Council, acting for both harvesters and processors of wild salmon, initiated the MSC certification process in September 2001. (*www.msc.org/*).
- The Audubon Green Leaf Eco-Rating Program. Hotels and other lodgings that enrol in this program receive a rating based on an evaluation of their policies and principles around water and energy conservation, waste reduction, and the use of hazardous substances. (*www.terrachoice.ca/hotelwebsite/indexcanada.htm*).

Going Green at Work or School: There are many opportunities for action at your workplace or school:

- Instead of relying on single passenger cars to travel to and from work or school, use mass transit, car or van pools, bicycles, and other alternatives to relieve traffic pressure on the environment.
- Make an effort to recycle, conserve energy and water, and reduce waste. For example, the Foreign Affairs Canada website (*www.dfait-maeci.gc.ca/sustain/EnvironMan/system/greenop/index-en.asp*) provides tips on "greening" your office, meetings, transportation, purchasing, human resources, and other work-related activities.
- At several universities in B.C., networks of students, faculty, staff, and community stakeholders are working together to move their institutions "beyond climate neutral." (*www.commonenergy.org/*).

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Air Quality

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Air Quality

BACKGROUND

Air pollution, especially "smog," is a long-standing issue of environmental quality with a history of regulatory efforts to address air pollution dating back half a century. The two main types of air pollutants that make smog are airborne particulate matter and ground-level ozone. Trends in the levels of both these pollutants are shown in the two key indicators in this paper. Other air pollutants include sulphur oxides, carbon monoxide, nitrogen oxides, and heavy metals.

Ground-level ozone and $PM_{2.5}$ (particulate matter that is smaller than 2.5 micrometres in size) are of particular concern because no safe threshold for exposure has been found. This means that even low levels of exposure may pose a health risk. Because of their impacts on human health, both ground-level ozone and particulate matter have been added to the list of toxic substances under the Canadian Environmental Protection Act (CEPA). A BC Lung Association report (2003) identified particulate matter as the air emission of the most concern in BC from a human health perspective. In 2005, a study modelling the impacts on health of improving air quality in the Lower Fraser Valley reported that a 10% improvement in annual average $PM_{2.5}$ and mean daily maximum ozone concentrations would produce health benefits valued at approximately $195 million annually by 2010 (BC Lung Association 2005). The benefits should come from a reduction in acute and chronic bronchitis and asthma, hospital admissions, emergency room visits, and mortality.

In 2000, the Canadian Council of Ministers of the Environment (CCME) endorsed Canada-Wide Standards (CWS) for $PM_{2.5}$ and ground-level ozone that include targets for both pollutants. British Columbia supports the CWS agreement for $PM_{2.5}$ and ozone, which committed the province to do the following:

- Develop and implement plans to achieve the CWS by 2010
- Establish programs to ensure continuous improvement and to continue to keep existing clean areas clean, and
- Regularly report on progress made toward meeting the above targets.

In setting targets, the agreement recognizes that there are no "safe" levels for particulate matter or ozone.

INDICATORS

1. Key Indicator: Percentage of monitored communities that are achieving the Canada-wide standard for particulate matter ($PM_{2.5}$) in B.C.

Suspended particulate matter (PM) is composed of tiny, airborne solid or liquid particles (other than pure water). Particles larger than 10 micrometres (μm) in diameter settle to the ground relatively quickly. Particles this size are less of a health concern because they tend to collect in the throat and nose, where they are eliminated through the digestive system or by sneezing, coughing and nose blowing.

Particles of less than 10 µm can be inhaled. Previous state of environment reporting on air quality focussed on particulate matter of 10 µm or less (PM_{10}). It is now known that the portion of these particles posing the greatest threats to health are those 2.5 µm in diameter ($PM_{2.5}$) or smaller (Liu 2004) that penetrate deepest into the lungs. These fine particles ("respirable particulate matter") are less than 1/20th the width of a human hair. Although there are health risks associated with particles larger than $PM_{2.5}$, steps taken to reduce exposure to the $PM_{2.5}$ fraction also reduces exposure to the coarser particles in PM_{10}.

Once in the lungs, fine particulate matter affects pulmonary function. It contributes to the development of bronchitis and aggravates bronchial asthma and chronic bronchitis, pulmonary emphysema, existing cardiovascular disease, and other lung-related problems. Senior citizens and people with existing lung or heart problems are most at risk, but healthy adults and children can also be affected. Epidemiological studies show a relationship between exposure to fine particles and adverse effects on heath, particularly for the most susceptible groups in the population. This includes people who have had acute lower respiratory diseases, cardiovascular diseases, chronic artery diseases, congestive heart failure, or diabetes. This also includes children with asthma, children under 2 years of age and those who spend more time outdoors. A recent review of the scientific literature (Hrebenyk et al. 2005) showed that adverse health impacts have been found at exposure levels below the current Canada-Wide Standard (CWS) for $PM_{2.5}$, at levels observed in some communities in B.C.

In addition to naturally occurring dust, sources of PM include soot and smoke emitted by motor vehicles and other forms of transportation (including marine vessels), power plants, factories, construction, residential and forestry-related wood burning, and other activities. Particulate matter is categorized by how it is formed. Primary particulate matter is released directly into the atmosphere through processes such as erosion or direct emission from industrial or burning processes, including forest fires. Particles produced by erosion or by grinding are typically larger than 2.5 µm, whereas those produced by high-temperature combustion are predominantly less than 2.5 µm in diameter (i.e. $PM_{2.5}$). Based on the 2000 provincial emission inventory, the largest sources of $PM_{2.5}$ were controlled burning for forest management (29%), wood industries (18%), and residential wood combustion (15%), the latter reflecting the fact that a large proportion of homes burn wood for heating (BCMOE 2005). Secondary particulate matter is formed in the atmosphere through chemical or physical transformations of a large number of different chemicals, including gases such as sulphur dioxide, nitrogen oxides, volatile organic compounds, and ammonia. Secondary particles are typically less than 2.5 µm in diameter and can be a large part of total $PM_{2.5}$, contributing to reduced visibility and summertime (photochemical) smog.

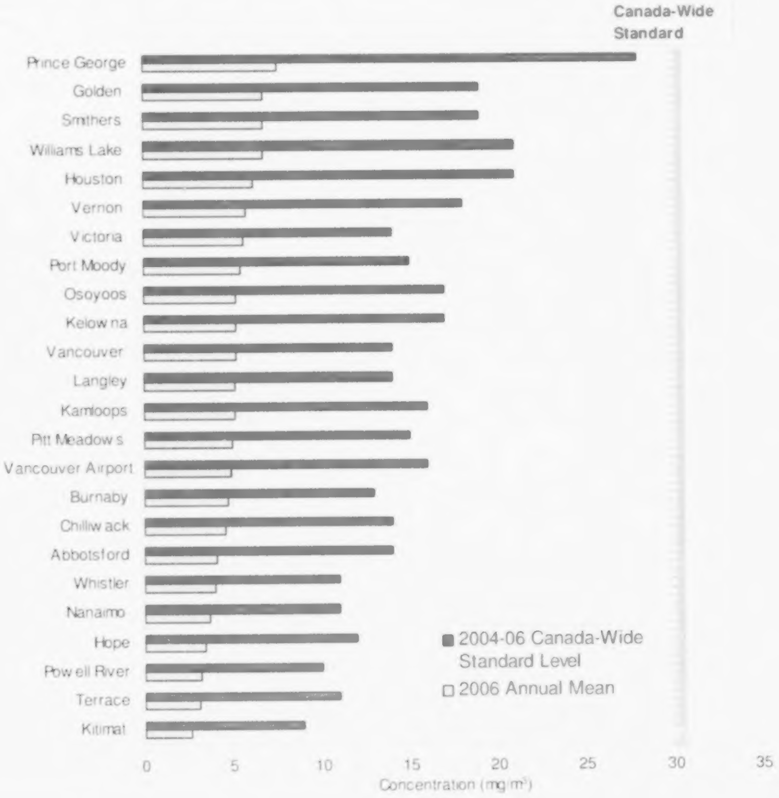
This indicator reports air quality with respect to achievement of the Canada-Wide Standard (CWS) for $PM_{2.5}$, as well as the annual averages for $PM_{2.5}$ in monitored communities. The annual averages are calculated as the average of all daily values available over the year. This differs from the way achievement of the CWS is calculated. Calculations for the CWS are based on the one daily value over the course of a year that is higher than 98% of all other daily values. These values are then averaged over three consecutive years.

Data and Methodology

Data for the $PM_{2.5}$ indicator (2004–2006) is gathered from a network of monitoring stations using continuous air samplers. The $PM_{2.5}$ monitoring network has expanded greatly over the past 6 years as the focus has shifted to monitoring smaller particles.

The Canada-Wide Standard (CWS) for $PM_{2.5}$ is 30 $\mu g/m^3$, averaged over a 24-hour period. Achievement of the standard is based on a 3-year running average of the annual 98th percentile ambient measurement. In the following analysis, the CWS is reported for continuous monitoring sites, irrespective of population. This reflects B.C.'s commitment to achieving the CWS in all monitored communities by 2010, and not just in communities larger than 100,000 population as specified in the CWS agreement.

Figure 1. Ambient levels of $PM_{2.5}$ at continuous monitoring stations across B.C. Annual mean for 2006 shown. Calculated Canada-wide Standard (CWS) value for 2004–2006 is also shown relative to the CWS (30 $\mu g/m^3$).



Source: B.C. Ministry of Environment.

Table 1. $PM_{2.5}$ concentrations (in μg/m^3) for sampling sites in B.C. using continuous (TEOM) samplers, 2004–2006.

	2004		2005		2006	
Site	Mean	CWS	Mean	CWS	Mean	CWS
Abbotsford Airport - Walmsley Road	5	15	5.2	15	4.1	14
Burnaby Kensington Park	4.9	–	4.9	14	4.5	13
Burnaby South	5.2	–	5.5	14	4.7	13
Chilliwack Airport	5	15	4.7	14	4.6	14
Golden Hospital	–	–	7.1	34	6.9	19
Golden Townsite	–	–	6.7	–	6.6	19
Hope Airport	–	–	4.5	–	3.4	12
Houston Firehall	6.2	22	6.2	22	6.2	21
Kamloops Brocklehurst	5.7	26	4.7	24	5.1	16
Kelowna College	5.8	25	4.6	23	5.2	17
Kitimat Rail *	4.1	12	3.7	12	–	–
Kitimat Riverlodge	2.9	11	2.7	10	2.6	9
Langley Central	–	–	5.6	17	5.1	14
Nanaimo Labieux Road	4.1	11	4.4	11	3.7	11
Osoyoos Canada Customs	–	–	4.1	–	5.2	17
Pitt Meadows Meadowlands Elem. Sch.	5.3	15	5.5	15	5	15
Port Moody Rocky Point Park	5.8	–	6	15	5.5	15
Powell River Cranberry Lake	3.2	10	3	10	3.2	10
Prince George Plaza 400	10.6	36	7.9	34	7.6	28
Quesnel Maple Drive	8.2	27	6.9	26	7.5	26
Quesnel Pinecrest Centre *	8.3	23	7.8	24	–	–
Quesnel Senior Secondary	8.9	27	7.3	25	8	24
Quesnel West Correlieu School	6.3	21	5.3	19	5.5	19
Saanich Stellys Cross Road	7.6	–	–	–	–	–
Smithers St Josephs	–	–	6.7	–	6.8	19
Terrace BC Access Centre	3.2	–	3.4	12	3.1	11
Vancouver International Airport #2	5.5	16	6	16	4.9	16
Vancouver Kitsilano	5.8	–	5.9	14	5.1	14
Vernon Science Centre	6.8	23	5.6	20	5.8	18
Victoria Royal Roads University	4.3	12	4.1	11	4	11
Victoria Topaz	5.6	16	5.4	15	5.6	14
Whistler Meadow Park	–	–	4	–	4	11
Williams Lake Columneetza School	7.2	24	6.7	22	6.8	21
Williams Lake CRD Library	6.5	19	5.6	18	5.6	18
Williams Lake Skyline School	7.5	22	6.7	21	6.5	21

Data Source: B.C. Ministry of Environment.

* Not shown in Figure 1: 2006 monitoring was not available.

Note: Mean = the annual average of all daily values for the year. CWS = calculated for achievement of Canada-wide Standards as one daily value that is higher than 98% of all other daily values (a running 3-year average).

Continuous measurements were obtained using a Tapered Element Oscillating Microbalance (TEOM). Continuous samplers use a heated inlet designed to exclude particles larger than 2.5 µm in diameter from the air sample stream. The air sample stream is drawn through a filter that sits at the end of a tapered tube. As the filter mass changes, the oscillating frequency of the tube changes. $PM_{2.5}$ concentrations can be determined through the corresponding frequency change.

The inlet air is heated to remove free water and to standardize sampling conditions. However, a drawback of this process is that a portion of the $PM_{2.5}$ may be volatilized by the high sampling temperature. Semivolatile materials such as ammonium nitrate and certain hydrocarbons are especially affected. Studies across Canada have indicated that annual average $PM_{2.5}$ concentrations may be underestimated by 1.5–3.0 $\mu g/m^3$, and annual 98th percentile concentrations underestimated by 4–15 $\mu g/m^3$ when compared with noncontinuous filter-based measurements (Dann and White 2005).

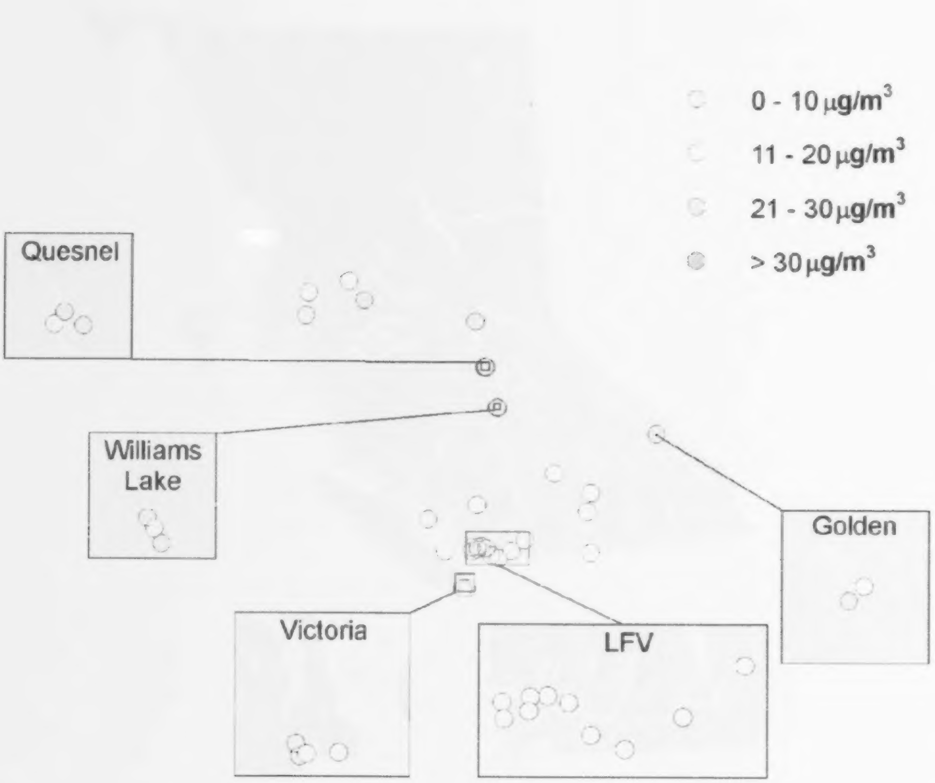
For the purposes of calculating achievement of the CWS, a daily value for $PM_{2.5}$ refers to the 24-hour average concentration of $PM_{2.5}$ measured from midnight to midnight (local time). For continuous monitors, at least 18 hourly measurements are required to calculate a valid daily value. An annual data set should be considered complete if at least 75% of the scheduled sampling days in each quarter have valid data.

Use of percentiles is a means of adjusting for differences in sample sizes and ensuring that the values used for determining achievement are not unduly affected by extreme events. The 98th percentile is the daily value out of a year of monitoring data below which 98% of all values fall. Jurisdictions calculate the 3-year average of annual 98th-percentile values, using the three most recent consecutive calendar years of monitoring data that meet annual data completeness criteria (CCME 2004).

Interpretation

Communities in the interior regions of the province typically have higher levels of $PM_{2.5}$ than coastal communities (Figure 2). This is due to a number of factors, including the large number of wood combustion sources and the greater frequency of light winds and inversions in interior communities. In 2006, all of the continuous monitoring sites in the province were below the CWS level.

Figure 2. Results of $PM_{2.5}$ continuous monitoring (TEOM sites) in 2006 compared to the CWS standard of $PM_{2.5}$ of 30 $\mu g/m^3$.


0 - 10 $\mu g/m^3$
11 - 20 $\mu g/m^3$
21 - 30 $\mu g/m^3$
> 30 $\mu g/m^3$
Quesnel
Williams Lake
Golden
Victoria
LFV

Source: B.C. Ministry of Environment.

Supplementary Information: Wood smoke in the air

A 1997 national survey of residential energy use found that about 40% of houses in BC had some type of wood-heating appliance or fireplace (NRC 1997). Smoke from wood heating and other types of wood burning contains fine particulate matter ($PM_{2.5}$) as well as larger particles, carbon monoxide, nitrogen oxides, sulphur oxides and volatile organic compounds. Table 2 shows the contribution to air pollution from residential wood burning alone in BC annually.

Table 2. Emissions from residential wood burning in B.C., 2003.

Emissions	Provincial total (tonnes/year)
CO	65,579
NOx	1,120
SOx	160
VOC	14,860
PM_{10}	10,632
$PM_{2.5}$	10,623

Source: BCMWLAP. 2005. Residential Wood Burning Emissions in British Columbia. *www.env.gov.bc.ca/air/airquality/pdfs/wood_emissions.pdf.*

In interior regions of the province, wood smoke is the largest contributor of fine particulate ($PM_{2.5}$) air pollution. There are an estimated 120,000 conventional wood burning stoves currently in use in BC (Xue and Wakelin 2006). Replacing these appliances with new, EPA/CSA-certified stoves would make a major difference to local air quality because certified stoves burn one-third less wood and produce 70% less smoke than older inefficient stoves.

A 1994 provincial regulation required that all new wood stoves installed in homes must be certified, and in 1995 the Ministry of Environment began a change-over program that gave incentives of $50 to $200 to replace older models with new technology. Despite this, a provincial survey in 2005 showed that only 1% of the existing stock of older stoves had been replaced despite local programs to encourage replacement (Gauvin and Wakelin 2005). Research showed that the barriers to success were the high cost of new stoves, accessibility of alternative fuels, and perception about wood smoke and wood burning (NRG Research Group 2006). To address these barriers in the Bulkley Valley-Lakes District, the province is partnering with Environment Canada, the Northern Health Authority, the regional district, and local retailers on a pilot program using community-based social marketing tools to encourage people to adopt clean burning technology. The pilot project combines education programs about operating wood stoves efficiently with funding incentives to exchange older models for new, low-emission appliances.

Regulatory requirements are also being brought in to speed replacement. In the Bulkley Valley-Lakes Regional District. Houston was the first jurisdiction to introduce a bylaw that requires residents to replace their non-certified woodstoves by 31 December 2010. Smithers and Burns Lake have also set target phase-out dates for conventional wood stoves of 2010 and 2012, respectively.

Ways to minimize the pollution from burning wood include the following:

- Burn only clean, dry wood. Never burn green, wet, painted, or treated wood or household garbage.
- Keep fires moderately hot, adding larger pieces of split wood as required.
- Avoid smoky, oxygen-starved fires by opening dampers enough to ensure the fire burns well.

- Don't burn on fair or poor air-quality days.
- Buy the right size of stove for the area to be heated. A stove that is too large will have to be damped down to maintain a comfortable temperature, creating more smoke.

2. Key Indicator: Percentage of monitored communities in B.C. that are achieving the Canada-wide standard for ground-level ozone

Ozone occurs naturally and is an important constituent of the upper levels of Earth's atmosphere, where it blocks harmful ultraviolet radiation from reaching the Earth's surface. However, at ground level ozone is an air pollutant harmful to human health and vegetation. Ground-level ozone is formed by chemical reactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of sunlight (Warneck 1988). The component compounds ("precursors") may come from local emissions such as fossil fuels burned by vehicles and industry, or may be transported in the air from other regions.

Ozone concentrations vary with location and time of day, depending on the intensity of sunlight, weather conditions, and air movement. Hourly concentrations in urban areas are typically highest in the summer when temperatures are highest, the sun is most intense, and longer days enhance photochemistry. Strong daily patterns are observed during this period, with concentrations peaking in the afternoon and decreasing through the night, from lack of sunlight and other chemical reactions.

There are natural sources of the chemical precursors to ground-level ozone. These include soil microorganisms and lightning that contribute NOx emissions; vegetation that contributes VOC emissions; and wildfires that contribute both NOx and VOC emissions. Down mixing of ozone from the stratosphere is a direct source of ozone, most likely to be observed during the spring and at higher elevations when conditions favour such intrusions (Health Canada and Environment Canada 1999).

The risks to human health from ground-level ozone depend on the amount inhaled, and the probability of health problems rising as ozone concentrations increase. Ozone exposure can increase respiration and heart rates, aggravate asthma, bronchitis and emphysema, and pain during inhalation. In general, these effects are linked to more emergency room visits, hospitalizations, absenteeism, lower labour force participation, and higher health care costs, as well as premature death (Willey et al. 2004).

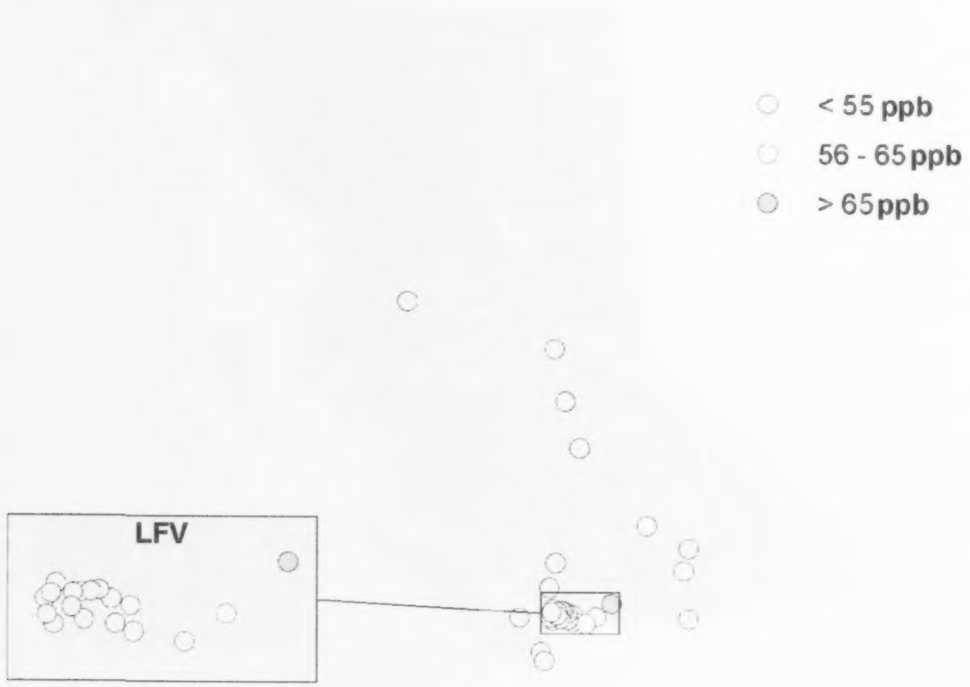
This indicator reports ground-level ozone concentrations with respect to achievement of the Canada-Wide Standard (CWS), as well as the annual averages in monitored communities. The annual averages are based on the average of all hourly values available over the year. This differs from the way calculations are done to show achievement of the CWS for ground-level ozone. This involves a series of calculations, in which the maximum 8-hour average concentration is determined for each day, then the 4th highest of these daily maximums is selected for each year. These values are averaged over 3 consecutive years.

Data and Methodology

The Canada-Wide Standard (CWS) for ground-level ozone is 65 parts per billion (ppb) averaged over an 8-hour period. Jurisdictions compute the 3-year average of the annual 4th-highest daily 8-hour average, using the three most recent consecutive calendar years of monitoring data that meet the annual data completeness criteria (CCME 2004).

Jurisdictions count a valid monitoring day as one in which 8-hour averages are available for at least 75% of the possible hours in the day (i.e., 18 of the 24 averages). However, if less than 75% of the 8-hour averages is available for a given day, it may still be counted as a valid day if the computed daily maximum 8-hour average is higher than 65 ppb. An annual data set is considered complete if daily maximum 8-hour average concentrations are available for 75% of the days during the period April to September.

Figure 3. Sampling sites (in red) in B.C. that exceeded the CWS standard for ground-level ozone (65 ppb) (2004–2006).



Source: B.C. Ministry of Environment.

Table 3. Ozone concentrations (in parts per billion, ppb) at sampling sites in B.C., 2004 to 2006.

	2004		2005		2006	
Site	Mean	CWS	Mean	CWS	Mean	CWS
Abbotsford Central	15	59	16	57	19	58
Burnaby	13	43	14	43	17	44
Burnaby Kensington Park	14	46	14	46	17	46
Burnaby Mtn	24	57	23	57	27	56
Campbell River	17	47	19	48	22	–
Chilliwack Airport	16	64	15	63	18	65
Coquitlam Douglas College	15	52	14	55	16	54
Eagle Ridge	–	–	–	–	–	–
Hope Airport	17	68	17	68	19	67
Kamloops Brocklehurst	19	60	20	59	22	57
Kelowna College	20	58	21	57	22	56
Langley Central	19	60	18	58	22	60
Maple Ridge Golden Ears Elementary School	16	60	16	59	19	62
Nanaimo Labieux Road	19	48	18	48	20	48
North Delta	15	48	14	48	17	48
North Vancouver Mahon Park	14	49	14	50	17	50
Osoyoos Canada Customs	–	–	27	–	30	53
Pitt Meadows Meadowlands Elem. Sch.	16	53	16	53	19	55
Port Moody Rocky Pt. Park	12	49	12	48	13	50
Prince George Plaza 400	20	55	18	53	19	51
Quesnel Senior Secondary	15	54	16	52	18	53
Richmond South	15	51	15	53	17	51
Saanich Stellys Cross Road	19	–	18	52	24	52
Smithers St. Josephs	18	50	17	52	19	52
Squamish	14	–	14	56	17	55
Surrey East	18	55	17	54	20	55
Vancouver International Airport	14	50	14	49	17	47
Vancouver Kitsilano	12	47	12	48	14	48
Vancouver Robson Square	7.5	36	7.5	37	8.9	36
Vernon Science Centre	12	45	12	44	14	43
Victoria Royal Roads University	20	50	21	51	–	–
Victoria Topaz	17	45	16	45	21	47
Whistler Meadow Park	18	54	18	54	20	54
Williams Lake Columneetza School	17	49	21	49	22	55

Source: B.C. Ministry of Environment.

Note: Mean = the annual average of all daily values for the year. CWS = calculated for the achievement of Canada-wide Standards from annual 4th-highest daily 8-hour average (3-year rolling average).

Interpretation

The highest annual mean concentrations of ground level ozone occur in the southern interior sites (e.g., Osoyoos and Creston), which experience very warm and sunny summers. In contrast, the lowest concentrations are measured in downtown Vancouver, where high NOx emissions remove the excess ozone (Table 3).

In calculating achievement of CWS, the highest concentrations of ozone were observed in the eastern Lower Fraser Valley. The monitoring site at Hope (Figure 3, in red) exceeded the CWS for ozone in each of the 3 past years, and Chilliwack has been within 2 ppb of the standard over the same time. Trends analysis shows that the maximum short-term (1-hour) concentrations have decreased in the Lower Fraser Valley between 1985 and 2000 (Vingarzan 2003), but it appears that annual mean concentrations in the western part of the valley are increasing. A contributing factor may be the increase in global background concentrations, including trans-Pacific transport of ozone from biomass burning and other human activities in Asia (McKendry 2005).

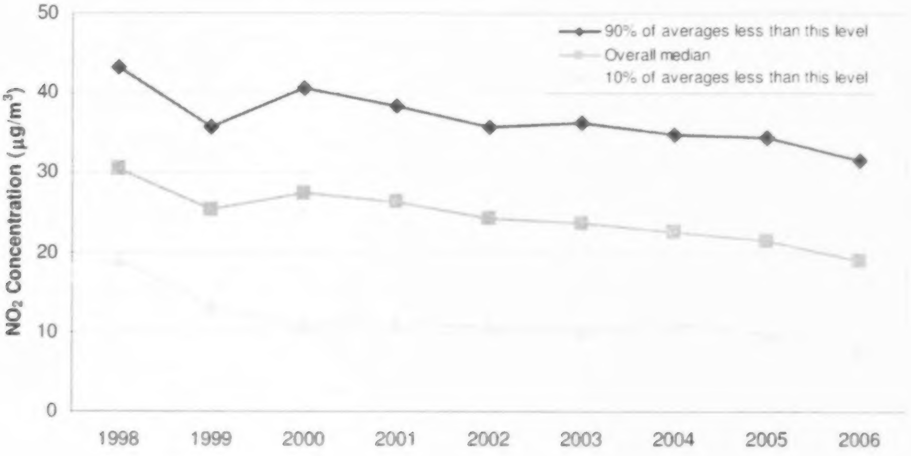
Supplementary Information: Trends in concentrations of nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) in B.C.

Nitrogen dioxide (NO_2) is one of the oxides of nitrogen (NOx), a group of highly reactive gases that form when fuel is burned at high temperatures. NO_2 is a very corrosive gas that contributes to ozone and secondary particulate formation and the reddish-brown haze associated with smog events. It is also harmful to health. NO_2 also reacts with water to form nitric acid, which is a component of acid rain. Most of the NOx emissions in BC come from transportation sources, such as vehicles and marine vessels, from non-road engines, the pulp and paper industry, and the oil and gas industry (BCMOE 2005).

The measurement of NO_2 is a 2-step process using the principles of chemiluminescence. First, the concentration of NO in the airstream is measured, using a gas-phase reaction of NO and ozone. This reaction gives off a quantity of light proportional to the concentration of NO. The second step involves passing the air stream over a heated catalyst to reduce all oxides of nitrogen to NO, then using the gas-phase reaction with NO and ozone to determine the total concentration of NO. The amount of NO_2 is the difference between the first measurement and the second measurement.

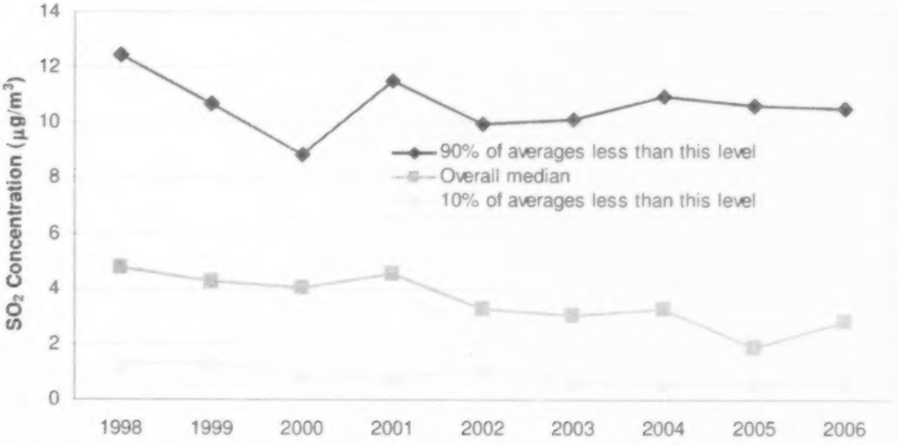
Urban areas tend to have higher levels of NO_2 as a result of the higher volume of traffic, as shown by the occurrence of the highest levels in Vancouver and Burnaby. The lowest levels were observed in areas such as Creston, Powell River, Kitimat, and Osoyoos. All BC communities monitored, however, met the Canadian annual objective for NO_2 of less than 60 $\mu g/m^3$. The graph (Figure 4) suggests that concentrations are declining, which would be consistent with an expected impact of more stringent emission standards for motor vehicles that have been adopted over the past decade.

Figure 4. Average NO_2 concentrations for sampling sites in B.C., 1998 to 2006.



Source: B.C. Ministry of Environment.

Figure 5. Average SO_2 concentrations for sampling sites in B.C., 1998 to 2006.



Source: B.C. Ministry of Environment.

Sulphur dioxide (SO_2) is a colourless gas that irritates the lungs and damages vegetation when it occurs in high concentrations. It comes from burning fossil fuels that contain sulphur and from processing ores that contain sulphur. The largest sources in the Lower Fraser Valley are marine vessels and the petroleum products industry, whereas in other parts of B.C., marine vessels, oil and gas and pulp and paper industries are the largest contributors (BCMOE 2005).

Monitoring for SO_2 is based on measuring fluorescent excitation of SO_2 by ultraviolet radiation. Where more than one monitor was located in a community, the one best representing regional air quality was presented. This may not include the site recording the highest concentrations in a community.

Trends in SO_2 concentrations are shown in Figure 5. In 2006, the highest annual average SO_2 concentration was in Trail, followed by Prince George, downtown Vancouver, and Kitimat. These are all communities with one or more industrial sources, or where marine, industrial, and motor vehicles are major sources. All B.C. communities except Trail met the B.C. annual objective for SO_2 of 25 $\mu g/m^3$.

WHAT IS HAPPENING IN THE ENVIRONMENT?

There has been a long history of monitoring and regulatory efforts to address the problem of "smog" and other forms of air pollution. B.C. now uses the Canada-Wide Standards (CWS) for fine particulate matter and ground-level ozone to measure achievement of objectives to improve air quality.

- In 2006, all communities with continuous air monitoring in B.C. were below the CWS for fine particulate matter (particles smaller than 2.5 micrometres). Only the levels in Prince George, which were the highest in B.C., approached the CWS threshold of 30 $\mu g/m^3$.
- Most communities in BC were below the CWS for ground-level ozone (65 parts per billion). The CWS for ozone was exceeded at Hope for the past 3 years, but readings at Chilliwack, Langley Central, and Maple Ridge were at or near the CWS threshold.
- In 2006 nitrogen dioxide readings in all communities were below the Canadian objective (60 microgram/m^3). In 2007, all communities, except Trail, met the BC annual objective for sulphur dioxide (25 microgram/m^3).

WHAT IS BEING DONE ABOUT AIR QUALITY?

Air quality management in B.C. is shared between federal, provincial, and local governments, with the provincial Ministry of Environment having the primary responsibility. Under the Canadian Environmental Protection Act (CEPA), the federal government sets National Ambient Air Quality Objectives (NAAQOs) as national goals for outdoor air quality. Provincial governments can adopt the NAAQOs or use them as benchmarks for setting provincial objectives or standards. Local and regional governments have the authority to restrict activities that emit air pollutants in their regions.

In 2000, the Canadian Council of Ministers of the Environment endorsed Canada-wide standards for ground-level ozone and fine particulate matter ($PM_{2.5}$). These standards set targets for ambient concentrations that have to be achieved by the year 2010.

Some key areas of work to improve air quality, such as programs to address diesel emissions, are jointly funded by several levels of government and the private sector working together. These include programs to retrofit school buses and municipal trucks with catalytic converters, replace diesel buses with natural gas buses, and encourage adoption of biodiesel fuel.

Federal Initiatives

Under the Canadian Environmental Protection Act (CEPA), the federal government assesses substances and controls their impact through national environmental quality objectives or regulations. The federal government regulates sources of air emissions such as motor vehicles and fuels, marine vessels, aircraft, railways, and other off-road engines, and is responsible for international agreements on air pollution.

Under CEPA, since 2002, emissions of air pollutants that affect human health and contribute to ground-level ozone, haze, and acid rain are tracked by Environment Canada in a national emissions inventory. The National Pollutant Release Inventory (available at www.ec.gc.ca/pdb/npri/npri_home_e.cfm) tracks emissions of particulate matter (total, PM_{10} and $PM_{2.5}$ sulphur oxides, nitrogen oxides, volatile organic compounds, carbon monoxide, and other pollutants).

Environment Canada is continuing to invest in new instruments to fill gaps in pollutant coverage at monitoring sites and to establish new monitoring sites. A priority is to upgrade the continuous $PM_{2.5}$ instruments and improve the monitoring of $PM_{2.5}$ during cold seasons (Environment Canada 2006). Increased monitoring in remote locations will improve the understanding of background air quality.

The federal government has also established new, more stringent engine and fuel standards for diesel engines. However, since these standards apply to newly manufactured engines, it will take 20 to 30 years to realize the full benefit of the reduced emissions as older engines are replaced.

Provincial Initiatives

The B.C. *Environmental Management Act* (EMA) gives the provincial government the authority to develop standards, objectives, and guidelines for protecting air quality. Under the EMA, air discharges must be authorized by the Ministry of Environment through permit, approval, order, or regulation. The legislation also includes provisions for area-based planning. Provincial legislation controlling particulate matter includes the following:

- Regulations limiting open burning of wood residues and emissions from wood stoves.
- Vehicle and fuel quality regulations.
- Regulations requiring the phase-out of beehive burners by the end of 2007.
- Emission limits for some industrial sources (e.g., coal-fired power plants).

The Open Burning Smoke Control Regulation is currently being revised (fall and winter 2007). The new regulation will be more protective of human health in community airsheds and more flexible in the working forests, while encouraging alternatives to open burning for disposing of woody debris.

Over the next three years, $13.5 million has been allocated to provincial clean air initiatives led by Ministry of Environment in partnership with industry, communities, and other levels of government. Planned initiatives include the following:

- Retrofitting diesel buses and heavy duty diesel vehicles (see text box).
- Providing incentives to reduce the use of conventional woodstoves.
- Encouraging industry to adopt better emission technologies.
- Eliminating beehive burners.
- Providing financial incentives to help municipalities shift to hybrids and retrofit diesel vehicles.
- Extending the $2,000 sales tax exemption on new hybrid vehicles.
- Creating electrified truck stops to reduce idling.
- Implementing elements of the BC Energy Plan (e.g., reduce emissions from oil and gas flaring).

The province has committed to achieve the CWS for $PM_{2.5}$ in all monitored communities by 2010. To support implementation of the CWS the province supports development of airshed plans in B.C. communities, and scientific studies (e.g. Golden, Prince George, and Kelowna) needed to support airshed decisions. Related activities in support of improved local air quality include:

- The Clean Air Toolkit (www.cleanairkit.ca), an online tool to help local governments develop emission reduction programs in their communities.
- Wood stove exchange programs and a pilot study in the Bulkley Valley-Lakes District to assess effective ways to encourage the exchange of conventional wood stoves with low-emission wood stoves.
- Increased biodiesel use in the province.
- Development of a GIS-based tool to produce local emission inventories for airshed planning.

DIESEL RETROFIT PROGRAM

On June 6, 2007, the provincial government announced that British Columbia would be the first province in Canada to make clean emission technology mandatory in older commercial transport diesel vehicles. The new regulation requires installation of Diesel Oxidation Catalyst (DOC) filters, or an equally effective technology, in about 7,500 older vehicles by 2009. In B.C., older on-road heavy-duty diesel vehicle (models from 1989 to 1993) are responsible for 6.8% of overall particulate matter pollution. This is a high proportion for a relatively small number of vehicles. Installation of each DOC unit costs about $1,200 to $2,500. DOC filters are one of the clean technology options that are easy to install on most vehicles and require virtually no maintenance. The filters do not affect vehicle performance or increase fuel consumption, and are compatible with biodiesel fuels. It is estimated that this new regulation will reduce particulate matter by up to 60 tonnes per year and contribute to improved local air quality.

British Columbia's AirCare® Program

In 1992, the British Columbia government initiated AirCare, a vehicle emissions inspection and maintenance program to reduce emissions from onroad motor vehicles. It was the first such program in Canada and it aimed to reduce smog-forming emissions from cars and light trucks in Vancouver and the Lower Fraser Valley. Under the program, vehicles are tested regularly (at 1- or 2-year intervals) and those identified with defective emission controls are required to be repaired. A later program, AirCare OnRoad for heavy duty diesel vehicles, was piloted in 1996 and re-launched by the Province in 2004.

A recent study of the impact of AirCare showed that over one inspection cycle (a 2-year period) the program reduces vehicle hydrocarbon emissions by 25%, carbon monoxide by 24%, and nitrogen oxides by 11% (Edwards et al. 2004). Together, the AirCare and AirCare OnRoad programs reduced regional air pollution by an estimated 5% fewer emissions (Edwards et al. 2004).

AirCare is now managed by TransLink, the transportation authority for the Lower Mainland. It is just one part of the broader Greater Vancouver Regional District Air Quality Management Plan. As a result of tighter federal emission standards for motor vehicles since 2004, AirCare, and other local emission reduction measures for point and area emission sources, Metro Vancouver accomplished the major objective of reducing total emissions of common air contaminants by 38% by 2000. (www.aircare.ca/)

The New Air Quality Health Index

After public testing in 2005, the Ministry of Environment began piloting a new Air Quality Health Index (AQHI) in 2006. The AQHI is a scale (1 to 10) developed by provincial and federal environmental and health professionals to inform the public of health risks from local air pollution conditions. It was designed to help people make decisions to protect their health (e.g., by limiting exposure or reducing activity when the levels are high).

The AQHI reports on the potential health effects as well as the quality of the air. This index is not the same as the Air Quality Index, which reports results of air quality monitoring but does not provide information on health risks. The AQHI is based on the relative risks of a combination of common air pollutants known to harm human health, including $PM_{2.5}$, ground-level ozone, and nitrogen dioxide. The AQI reports the index for the single pollutant with the highest concentration relative to environmentally-based regulatory criteria.

In the pilot phase (2006/07), the AQHI is provided for 14 communities around the province on a website that updates automatically. The website shows recent and current air quality conditions expressed on a scale of 1 to 10 in terms of the risks to health; it also provides predicted conditions for the next day. The website also provides specific health messages for people who are sensitive to air quality, thus the people most at risk. (www.airplaytoday.org)

In 2008 the AQHI for all monitoring locations in B.C. and across Canada will be provided from a national Environment Canada website (*http://WeatherOffice.gc.ca*).

Regional Initiatives

The provincial government has delegated authority for air quality management to the Greater Vancouver Regional District (Metro Vancouver). The Fraser Valley Regional District (FVRD) has been delegated the authority for air quality planning. Under the BC *Environmental Management Act*, the provincial government can designate an area or airshed for the purpose of developing area-based management plans, such as air quality management plans. However, to date all air quality planning efforts have been voluntary. Local air quality plans vary significantly from one area to another to take into account differences in the type of pollutants and sources, such as particulate matter from wood stoves and debris burning and SO_2 from industrial sources.

Table 4. Local air quality management programs and plans developed in B.C. (as of July 2007).

Plans in place	Drafted plans in progress 2007	Pre-planning stage
Metro Vancouver (Greater Vancouver Regional District)	Sea-to-Sky (will include Whistler)	Golden (intensive monitoring for source of PM)
Fraser Valley Regional District		
Whistler		
Regional District of Okanagan-Similkameen		
Regional District of Central Okanagan		
Regional District of North Okanagan		
Quesnel		
Williams Lake		
Prince George		
Bulkley Valley - Lakes District		
Merritt		

WHAT CAN YOU DO?

Any steps that you take to reduce the amount of fuel burned, whether it is in transportation, home heating, or other uses will help reduce the emission of air pollutants.

- Insulate your home and take other steps to reduce the use of home-heating fuels.
- Replace older wood stoves with EPA/CSA certified wood burning appliances. Keep smoke emissions low by burning only dry, well-seasoned wood in a moderately hot fire.
- Keep your vehicle tuned correctly to avoid excessive tailpipe emissions.
- Purchase a fuel-efficient car, use public transportation, bicycle or walk to reduce the amount of fuel burned.
- Avoid unnecessary vehicle idling. Idling a vehicle for longer than 10 seconds requires more fuel than stopping and restarting the engine.
- Use manual or electric lawn mowers, leaf blowers, and weed trimmers instead of gas-powered models. The small engines in yard equipment, particularly older 2-stroke models, emit high levels of air pollutants per litre of fuel burned.
- Instead of backyard burning, recycle or compost waste and yard debris. Not only does backyard burning contribute particulate matter to the air, it is now known to be a main source of new dioxin and furan contamination deposited in the local environment (Lemieux et al. 2000) (For more information see: www.env.gov.bc.ca/soe/bcce/02_industrial_contaminants/technical_paper/industrial_contaminants.pdf).

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Fresh Water

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Fresh Water

BACKGROUND

Although water covers nearly three-quarters of Earth's surface, only 3% is freshwater in some form. Most of that small fraction is found in glaciers or is underground—only a tiny percentage of the world's freshwater occurs as surface water. Canada is more fortunate than most countries because the country's landmass contains approximately 9% of the world's renewable water supply (water replenished by precipitation on a short-term basis) (NRCan 2006). This may sound like a great deal of water, but concern about water quality and supply is increasing with the increasing demand on water resources by a growing population and the effects of climate change on precipitation patterns and glacial melting.

A clean and adequate water supply is a necessity for the health of all living organisms and ecosystems, including people and their activities. Fresh water supports the agriculture, fisheries, and forests on which society depends for food, clothing, and shelter, as well as for recreational and cultural pursuits.

Indicators in this paper focus on three aspects of fresh water in British Columbia: surface water quality, groundwater supply and water use. They are indicators of the need for, and progress in, action on water resource stewardship to ensure the future sustainability of water resources.

INDICATORS

1. Key Indicator: Water quality index for surface water bodies in B.C., 2002–2004

The quality of surface fresh water, as measured by the Water Quality Index (WQI) is a state or condition indicator. The WQI is a tool that allows a large number of water quality characteristics for a particular body of water to be expressed as a simple rating. It shows the overall quality of a water body in relation to the uses for that water, such as habitat for aquatic life, irrigation, recreation, or drinking water. The first WQI was developed in British Columbia in 1995. An interjurisdictional committee of water quality experts adapted the index for use nationally through the Canadian Council of Ministers of the Environment (CCME 2006). In general, this tool helps to answer the question: How good is the water quality?

Water quality variables are numerical measurements of the physical, chemical, and biological characteristics of water. Variables include physical characteristics, nutrients, metals, major ions, and other compounds such as pesticides. Guidelines for the different variables have been established through research. When these guidelines are exceeded, there is a risk of adverse effects.

Not all variables are measured—or are relevant—for every water body sampled. Different subsets of variables apply to different sites, according to the water quality objectives for the site.

"Water quality objectives" are limits set for water quality characteristics by the Ministry of Environment or by Environment Canada to protect all designated uses of a specific water body. The objectives take into account the local water quality conditions and uses and establish a reference against which the state of water quality in the water body can be measured. "Guidelines" are safe levels of water quality characteristics that apply province-wide or nationally to protect sensitive uses of water such as drinking, aquatic life, agriculture, and recreation. Guidelines are used when objectives have not been established for a water body; they provide a general reference against which the state of water quality can be checked.

The water quality index is a measure of how the water quality variables compare to the water quality guidelines or objectives for a specific site. The results of the comparisons for the relevant variables are combined to provide a water quality ranking for an individual water body.

Results reported in this indicator are not exactly comparable to WQI results reported in previous Environmental Trends in British Columbia: 2002 and therefore data from this indicator cannot be compared with earlier reports to show trends.

Methodology and Data

The WQI combines three aspects of water quality relative to water quality objectives:

- **Scope:** The number of variables that do not meet objectives in at least one sample during the time period under consideration, relative to the total number of variables measured.
- **Frequency:** The number of times that individual measurements do not meet objectives, relative to the total number of measurements taken in the relevant time period.
- **Amplitude:** The amount by which measurements that do not meet the objectives actually depart from those objectives.

These three factors are combined to form a numerical rating for a water body that falls into one of the five categories described below. These rankings describe the state of the water quality compared to the desirable or natural state for that water body.

Rating scale used for the CCME Water Quality Index (CCME 2006)

Excellent	95 to 100	Conditions are very close to natural or pristine levels. These index values can be obtained only when measurements never, or very rarely, exceed water quality guidelines.
Good	80 to 94	Water quality is protected with only a minor degree of threat or impairment. Measurements rarely exceed water quality guidelines and, usually, by a narrow margin.
Fair	65 to 79	Water quality is usually protected but occasionally threatened or impaired. Measurements sometimes exceed water quality guidelines and, possibly, by a wide margin.
Marginal	45 to 64	Water quality is frequently threatened or impaired. Measurements often exceed water quality guidelines and/or by a considerable margin.
Poor	0 to 44	Water quality is almost always threatened or impaired. Measurements usually exceed water quality guidelines and/or by a considerable margin.

Selection of water bodies: Water bodies were selected for monitoring if they were generally pristine or received industrial, municipal, or agricultural discharges and were therefore potentially at risk of being polluted. Monitoring focuses on water bodies that are likely to become, or already are, affected by human activities. It is important to note that most of the thousands of water bodies in the province are not monitored.

Sampling frequency and timing: Water samples are collected at times of the year when the water quality threshold is most likely to be exceeded. The WQI rating is based on the attainment of water quality objectives during these critical months.

To be included in calculations, the minimum requirement for lakes was 6 samples taken between 2002 and 2004; for rivers, it was at least 12 samples. In practice, most sites were monitored at least twice a month. This higher monitoring frequency has been shown to increase the chances of measuring concentrations that are higher than the water quality objectives.

Water quality characteristics: The range of measurable water quality variables includes nutrients, metals, physical characteristics (e.g., pH, dissolved oxygen, turbidity, and suspended solids), major ions (e.g., chloride, sulphate), and other compounds. Water quality characteristics measured at a given sampling station can include any of the following: levels of nitrate, fecal coliforms, cyanide, total dissolved gases, dissolved oxygen, suspended solids or sediments, nutrients, zooplankton, algae, trace metals, major ions, pH, and temperature.

Establishing the WQI: Acceptable threshold levels or concentrations are set for the water quality characteristics measured for each water body monitored. These levels depend on the water uses identified for the water body, such as drinking, recreation, irrigation and livestock watering, and use by aquatic life and wildlife. Note that drinking water in this context always refers to the quality of the source water before any treatment, before it is delivered to a consumer's tap (even if raw water is rated as excellent, it always goes through purification processes such as disinfection before distribution for drinking).

For the 2002–2004 reporting period, the focus was on determining the rating for each water body for the protection of only one water use—habitat for aquatic life, which is the most sensitive use for most water quality variables. Using the same set of objectives for one use (aquatic life) for all water bodies overcomes a problem with past reporting, which was that ratings for water bodies were not comparable because they protected different uses and therefore used different objectives.

Calculations were made using an index calculator available on the CCME website at *www.ccme.ca/ourwork/water.html?category_id=102*. For the period considered, the user supplied the data and the site-specific objectives. Using the calculator, the following were determined for each site: the number of variables that did not achieve the objective at least once, the number of times and places that the objectives were not met, and the largest amount by which any objective was not met. Methods used in the calculations are outlined in the Canadian Water Quality Guidelines for the Protection of Aquatic Life: CCME Water Quality Index 1.0 User's Manual (CCME 2001) (*www.ccme.ca/assets/pdf/wqi_usermanualfctsht_e.pdf*).

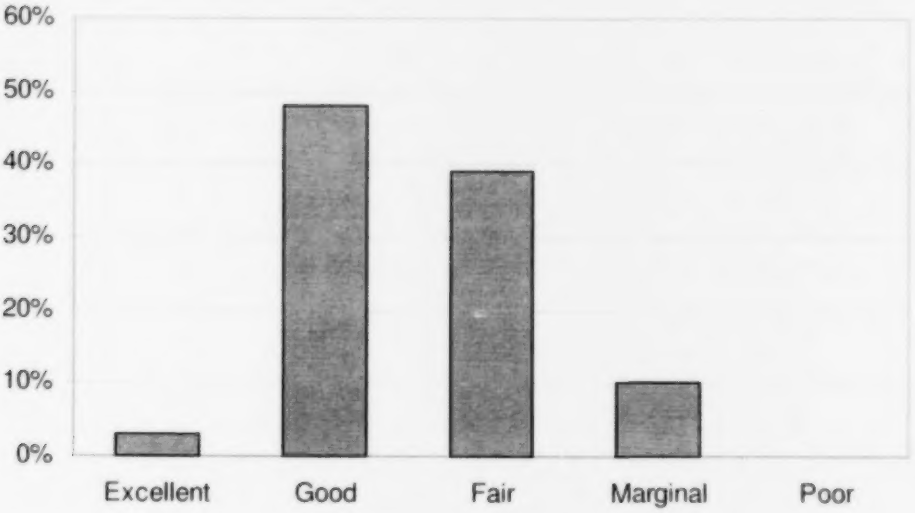
Caveats:

Index comparisons should be made only when the same sets of objectives are being applied for the water body and only when measuring the same sets of variables. The index should be based either on site-specific objectives or on guidelines for variables that have been ranked as the most important and relevant for the site. Including irrelevant variables can give unrealistically high (i.e., better) index values.

The WQI rank for a water body is sensitive to the number of water quality objectives, so generally a minimum of about eight objectives were applied to each water body. Where there are a greater number of threats to water quality, using a greater number of additional objectives (such as nitrate, ammonia, dissolved oxygen, bacteria, etc.) produces a more stable rank.

The WQI was calculated for 31 water bodies, including streams, rivers, and lakes, for which sufficient data were collected between 2002 and 2004 (Figure 1, Table 1).

Figure 1. CCME Water Quality Index ranks for sites in B.C., 2002–2004, as a percentage of the 31 sites tested.



Source: BC Ministry of Environment

Table 1. CCME Water Quality Index ranks for sampling sites in B.C., 2002–2004.

Location	Score	WQI rank
Beaver River near East Park Gate	88.4	Good
Columbia River at Birchbank	87.2	Good
Columbia River at Waneta	80	Good
Elk River at Highway 93 near Elko	73.2	Fair
Elk River at Sparwood	65.1	Fair
Fraser River at Hansard	82.7	Good
Fraser River at Hope	84.2	Good
Fraser River at Marguerite	74.2	Fair
Fraser River at Red Pass	100	Excellent
Illecillewaet River at Park Entrance	82.6	Good
Iskut River below Johnson River	91.7	Good
Kettle River at Carson	71	Fair
Kettle River at Midway	76.7	Fair
Kicking Horse River above Field, BC	87.2	Good
Kootenay River at Creston	71.1	Fair
Kootenay River at Kootenay Crossing	88.5	Good
Kootenay River near Fenwick Station	67.9	Fair
Myers Creek at International Boundary	65.2	Fair
Nechako River at Prince George	92.8	Good
Okanagan River at Oliver	70.8	Fair
Peace River above Alces River	84.2	Good
Pend'Oreille River at Waneta	85.3	Good
Quinsam River near the Mouth	65.3	Fair
Salmon River at Hyder	61.1	Marginal
Salmon River at Salmon Arm	45.8	Marginal
Similkameen River at Princeton	83.2	Good
Similkameen River near International Border	82.7	Good
Skeena River at Usk	82.7	Good
St. Mary at Wycliffe	60.2	Marginal
Sumas River at International Boundary	68.1	Fair
Thompson River at Spences Bridge	65.2	Fair

Source: BC Ministry of Environment

Results show that 51% of B.C. water bodies tested (2002–2004) were classed as either Excellent or Good, 39% Fair, only 10% Marginal, and none Poor. This compares favourably with the national breakdown for the same period, where 44% of water bodies were classed as Excellent or Good, 31% Fair, and 25% Marginal or Poor. However, this does not necessarily mean that water quality in B.C. is better than the national average. The national average could be skewed depending on the number and location of the water bodies selected for monitoring in each jurisdiction. It would also depend on whether jurisdictions used generic guidelines as objectives instead of site-specific water quality objectives that were used in B.C.

It is not possible to determine if there are trends in the WQI scores for individual sites in comparison to past years since new objectives were developed to ensure that scores were applied consistently across all sites. As well, data were not available for some sites used in the past and new sites have been added for reporting. Monitoring will continue at most of these sites and will eventually provide trends in water quality in future.

2. Secondary Indicator: Trends in surface water quality in B.C.

The trend in water quality for selected water bodies, over time, is a status or condition indicator. In general, it addresses the question: Is the water quality improving or decreasing?

The quality of water is a major concern because of the impact it has on the suitability of water sources for human and natural uses. This indicator shows the direction of departure (if any) of water quality from an acceptable threshold for each water body. The environmental significance of each trend is assessed in relation to water quality objectives for each water body or to province-wide water quality guidelines.

Methodology and Data

Environment Canada and the B.C. Ministry of Environment have been collecting technical data on surface water quality for many years through the Canada–B.C. Water Quality Monitoring Agreement. Data are from a network of water sampling stations throughout the province. (Many of these sites are the same monitoring stations used for the Water Quality Index described in Indicator 1.)

Selection of water bodies: Greater efforts are being made to monitor water bodies in areas of high human activity; therefore, the water bodies selected tend to represent water quality in developed watersheds around the province. That means that overall trends should not be considered as representative of water quality trends in the province as whole.

Sampling frequency and timing: Depending on the type of water body, sampling is carried out weekly, biweekly, monthly, or annually. Most rivers are monitored biweekly. Lakes and streams are usually monitored at least once per month, although some lakes may be monitored once per year, in the spring when the water is well mixed. Bottom sediments are less variable than surface waters and can be sampled annually or even once every few years.

Water quality characteristics: For a given water body, water quality measures can include some or most of the following: levels of nitrate, fecal coliforms, cyanide, total dissolved gases, dissolved oxygen, suspended solids or sediments, nutrients, zooplankton, algae, trace metals, major ions, pH, and temperature.

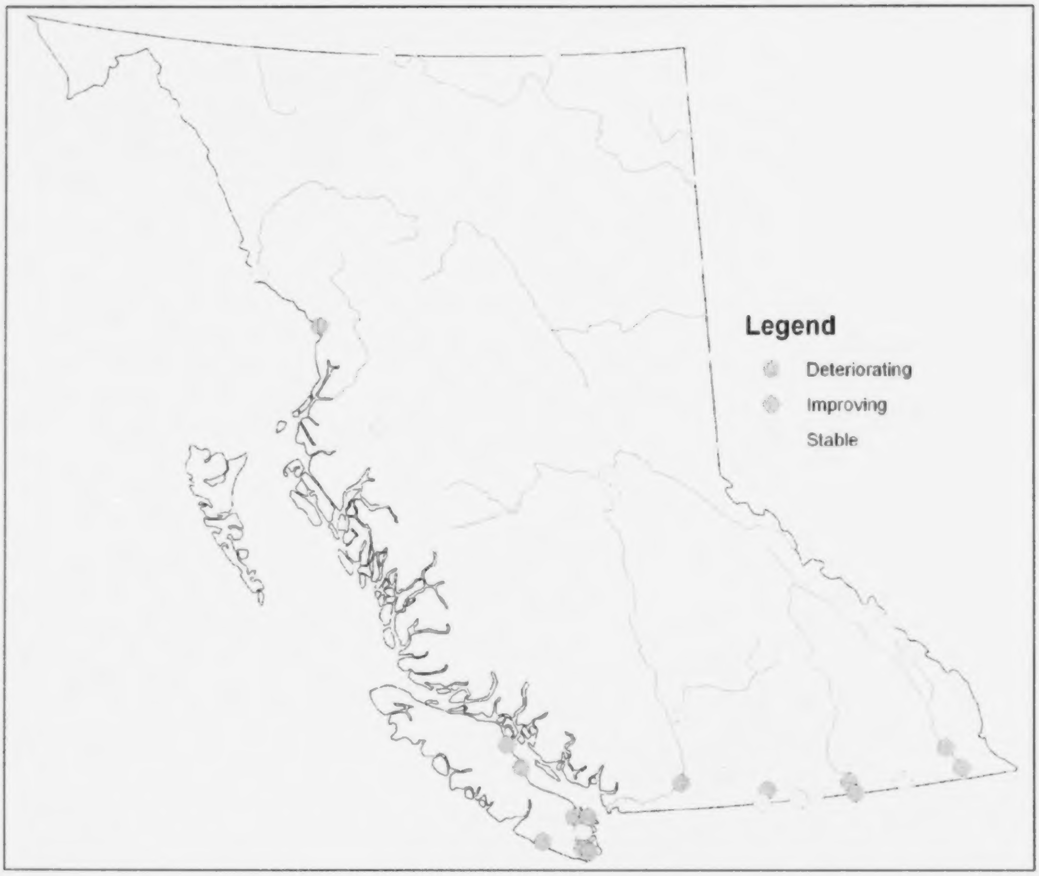
Analysis of trends: Trends were determined by plotting water quality measurement values on a graph over time together with the relevant water quality objectives or guidelines. Water quality objectives are limits set for water quality characteristics by the Ministry of Environment or by Environment Canada to protect all designated uses of a specific water body. Objectives take into account the local water quality conditions and uses and establish a reference against which the state of water quality in the water body can be measured. Guidelines are safe levels of water quality characteristics that apply province-wide or nationally to protect sensitive uses of water such as drinking, aquatic life, agriculture, and recreation. Guidelines are used when objectives have not been established for a water body to provide a general reference against which the state of water quality can be checked.

After the water quality values were plotted, the graph was inspected for significant trends with respect to environmental conditions. Trends that were increasing or decreasing over time and that appeared to show an important change in water quality were checked to determine whether the trend was a result of measurement errors, to test for statistical significance, and to identify the cause of any real change.

The condition of each water body was classified into one of three categories (Improving, Stable, Deteriorating) according to the trend in water quality for that site compared to water quality objectives or guidelines and are listed in Figure 2 and Tables 2, 3, and 4. Note that within each category, there is no ranking to account for the amount by which a water body had departed from the objectives or guidelines. Where other concerns for water quality were identified, these were so noted.

Trends in surface water quality are based on regular and consistent long-term monitoring. Of the 38 stations on water bodies included in this analysis (Tables 2 to 4), most have at least 10 years of data collected between 1980 and 2000 (or later, in some cases), and some have more than one sampling station. Before 2000, about 17 monitoring stations were terminated; most had no water quality concerns or the concerns were related to natural conditions. Twelve new stations were added between 2002 and 2006 (listed in Table 5). The new stations do not yet have enough records to show trends, but in future years will provide data for trend reporting. One station was terminated since reporting in 2002, Myers Creek (1998–2002), because a proposed mine in the United States that could have affect water quality has not proceeded; monitoring will resume if the proposal proceeds.

Figure 2. Trends in water quality at monitoring stations in B.C.


Legend
● Deteriorating
● Improving
Stable

Source: B.C. Ministry of Environment 2007. Data from Tables 2 to 5, below.

Table 2. Water quality monitoring stations in B.C. showing improving water quality.

Location of monitoring station (years of records)	Water quality concerns monitored	Cause of trend	Water use at risk
Columbia River at Birchbank (1983–2000)	Iron, aluminium	Dams/reservoirs	Drinking water, aquatic life
Columbia River at Waneta (1983–2000)	Cadmium, iron, chromium, lead, zinc, fluoride, sulphate, phosphorus	Waste abatement	Aquatic life, drinking water, irrigation, recreation
Cowichan River (1999–2003)	Phosphorus	Waste abatement	Drinking water
Fraser River at Hope (1979–2004)	AOX, Chloride	Waste abatement at pulp mills	Aquatic life and human and wildlife consumption of aquatic life
Fraser River at Marguerite (1985–2004)	AOX, Chloride	Pulp mill waste abatement	Aquatic life, wildlife, and their human consumers.
Fraser River at Red Pass (1985–2004)	Lead	Removal from gasoline	Aquatic life, drinking water
Kootenay River at Fenwick Station (1991–2000)	Zinc	Waste abatement	Aquatic life
Langford Lake (1979–98)	Phosphorus	Lake aeration and unknown	Aquatic life, recreation.
Lizard Lake (1985–95)	Phosphorus	Unknown	Aquatic life, recreation.
Maxwell Lake (1985–95)	Phosphorus	Unknown	Drinking water
Old Wolf Lake (1985–95)	Phosphorus	Unknown	Aquatic life, recreation.
Pyrrhotite Creek (Tsolum River) (1985–98)	Copper	Mine reclamation	Aquatic life
Salmon River near Hyder, Alaska (1990–2001)	Cyanide	Uncertain	Aquatic life, wildlife.
Shawnigan Lake (1976–98)	Phosphorus	Unknown	Drinking water, aquatic life, recreation.
Stocking Lake (1985–95)	Phosphorus	Unknown	Drinking water

Source: B.C. Ministry of Environment, Water and Sediment Quality Monitoring Reports, *www.env.gov.bc.ca/wat/wq/wq_sediment.html#data.*

Table 3. Water quality monitoring stations in B.C. showing stable conditions.

Location of monitoring station (years of records)	Concerns monitored (if any)	Cause of past trend (if any)	Water use formerly at risk (if any)
Beaver River in Glacier National Park (1987–95)		No past trend	
Fraser River at Marguerite (1985–2004)	Fecal coliforms	Improved sewage treatment	Drinking water, recreation and irrigation
Fraser River at Red Pass (1985–2004)		No past trend	
Fraser River at Stone (1990–1997)	AOX	Pulp mill waste abatement	Aquatic life, wildlife and their human consumers
Illecillewaet River in Glacier National Park (1987–95)		No past trend	
Iskut River below Johnson River (1981–2002)		No past trend	
Kettle River at Carson (1980–2002)		No past trend	
Kettle River at Midway (1980–2002)		No past trend	
Kickinghorse River above Field (1987–95)		No past trend	
Koksilah River at Highway #1 (1999–2003)		No past trend	
Kootenay River at Creston (1979–2000)	Phosphorus	Dam/reservoir	Aquatic life (declining Kootenay Lake fish production)
Kootenay River at Kootenay Crossing (1987–95)		No past trend	
Liard River at Fort Liard (1984–95)		No past trend	
Liard River at Upper Crossing (1983–94)		No past trend	
Myers Creek at International Boundary		No past trend	
Nechako River at Prince George (1985–2004)		No past trend	
Salmon River at Salmon Arm (1985–2004)	Fecal coliforms	Agricultural non-point source abatement	Recreation, irrigation and livestock watering
Similkameen River at Princeton (1989–97)		No past trend	
Similkameen River near US Border (1979–2000)	Arsenic	Unknown	Aquatic life and drinking water
Skeena River at Usk (1985–94)		No past trend	
Thompson River at Spences Bridge (1985–2004)	Chloride, dioxins & furans in fish	Pulp mill waste abatement	Aquatic life and human and wildlife consumption of aquatic life

Source: B.C. Ministry of Environment, Water and Sediment Quality Monitoring Reports, *www.env.gov.bc.ca/wat/wq/wq_sediment.html#data.*

Table 4. Water quality monitoring stations in B.C. showing deteriorating trends in water quality.

Location of monitoring station (years of records)	Water quality concerns monitored	Cause of trend	Water use at risk
Elk River (1984–2000)	Selenium	Coal mining	Aquatic life
	Nitrogen	Coal mining	Recreation
Fraser River at Red Pass (1985–2004)	Nickel	Natural erosion	None
	Manganese	Surface runoff form highway	Aquatic life
Okanagan River at Oliver (1980–2002)	Chloride	Irrigation return flows	Aquatic life
Quamichan Lake (1973–2001)	Fecal coliforms	Waterfowl	Recreation (swimming)
Quinsam River (1986–2004)	Sulphate & other major ions	Coal mining	Aquatic life - potential effects no direct threats at present
Salmon River at Salmon Arm (1988–2004)	Turbidity, Chloride	Agricultural and forestry non-point sources	Aquatic life, recreation

Source: B.C. Ministry of Environment, Water and Sediment Quality Monitoring Reports, *www.env.gov.bc.ca/wat/wq/wq_sediment.html#data.*

Table 5. New water quality monitoring stations in B.C. added since the previous report (sufficient data is not yet available from these stations for trends analysis).

Location of monitoring station (start year)	Water quality issues or concerns
Callaghan Cr at Callaghan Lake (2004)	Control for increased point and non-point source from Whistler (Olympics)
Callaghan Cr at Highway 99 (2004)	Increased point and non-point source from Whistler (Olympics)
Cheakamus R at Cheakamus Lake Rd (2004)	Control for increased point and non-point source from Whistler (Olympics)
Cheakamus R D/S STP (2004)	Increased point and non-point source from Whistler (Olympics)
Chilcotin R u/s Christie R Bridge (2005)	Impacts of climate change on ice fields and pine beetle harvesting
Columbia River at Nicolson (2003)	Upstream control for Columbia and important wetland
Dean River below Anahim Lake (2006)	Impacts of climate change
Elk River below Sparwood (2002)	Impacts of coal mining
Englishman R at Highway 19 (2004)	Non-point sources (logging, agriculture, urban)
Horsefly River above Quesnel Lake (2006)	Non-point sources (logging, agriculture, mining)
N Alouette R at 132nd (2004)	Non-point source impacts from planned urban development
San Juan River at Island Rd (2004)	Non-point sources (forestry)

Source: L. Swain, B.C. Ministry of Environment, pers. comm.

Results of trend assessments at 38 water quality sampling stations showed 13 improving, 18 stable, and 4 deteriorating. Three other stations had mixed trends. Although the water at Fraser River at Red Pass is close to pristine, the station appears in all three tables because different contaminants had different trends: lead levels were improving while others were stable or, in the case of nickel and manganese, deteriorating. Two monitoring stations appear in two tables: Salmon River at Salmon Arm (deteriorating turbidity from non-point sources, but stable fecal coliform levels) and Fraser River at Marguerite (stable fecal coliforms and improving AOX and chloride levels). Most of the trends are based on ten or more years of data collected from the early 1980s to the 1990s or as late as 2005.

Other monitoring sites showing deteriorating water quality in the measured parameters were Quamichan Lake (fecal contamination from naturally high waterfowl populations), Quinsam and Elk rivers (industrial effluent from coal mining), and Okanagan River at Oliver (increased dissolved solids, possibly from irrigation return flows).

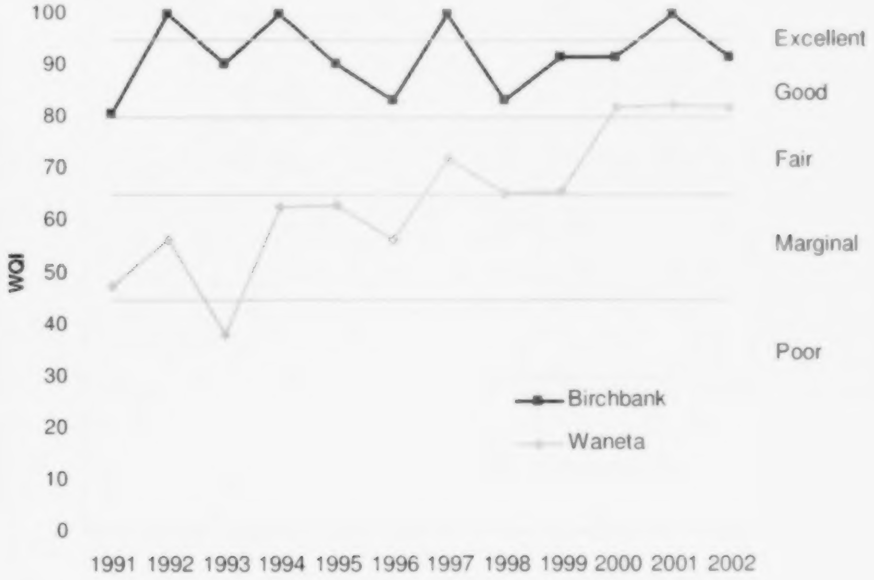
Supplementary Information: Lower Columbia River Water Quality Integrated Environmental Monitoring Program

Formed in 1991, The Columbia River Integrated Environmental Monitoring Program (CRIEMP) was initiated by stakeholders to monitor the Lower Columbia River (that portion between the Hugh Keenleyside Dam west from Castlegar, to the Waneta Dam at the Canada–US border). This 60-km stretch of river is affected by three large dams, by a pulp mill, a sawmill, a smelter at Trail, by municipal wastewater discharges from Castlegar, Trail, and smaller communities, and by non-point sources of contaminants from urban, industrial, and agricultural sources.

The first comprehensive environmental study of the river was released in 1994 (BCMOE 1994b). As a result, industry along the river made major changes that resulted in significant improvement to the environmental quality in the Lower Columbia River. Among them, the Zellstoff Celgar pulp mill upgraded their plant and changed bleaching processes to eliminate discharges of dioxins, furans, and other chlorinated organic compounds. Teck Cominco Metals installed a new smelter, closed a phosphate fertilizer plant, stopped discharging slag to the river, and improved effluent treatment.

Evidence of the effort to reduce impacts on the river can be seen in comparing the water quality index (WQI) scores for two sites over time (Figure 3, Table 6). Water quality at Birchbank, about halfway between Castelgar and Trail, has been rated as Good to Excellent since the early 1990s. In the early 1990s, water quality at Waneta, downstream from Trail near the US border, was rated Poor to Marginal. In the late 1990s water quality at the Waneta site had improved to Fair and in 2000 had improved to Good. The improvement in water quality is likely a result of steps taken to improve and modernize industrial plants and the cessation of discharges from upstream sources (CRIEMP 2005).

Figure 3. Trends in Water Quality Index results for two sites on the Lower Columbia River in January, 1991–2002.



Source: Columbia River Integrated Environmental Monitoring Program.

Table 6. Water Quality Index results for two sites on the Lower Columbia River in January, 1991–2002.

Year (January)	Waneta	Birchbank
1991	47.7 Marginal	80.6 Good
1992	56.5 Marginal	100 Excellent
1993	38.3 Poor	90.4 Good
1994	62.7 Marginal	100 Excellent
1995	63.0 Marginal	90.4 Good
1996	56.4 Marginal	83.5 Good
1997	72.1 Fair	100 Excellent
1998	65.3 Fair	83.5 Good
1999	65.8 Fair	91.7 Good
2000	82.0 Good	91.7 Good
2001	82.5 Good	100 Excellent
2002	81.9 Good	91.7 Good

Source: Columbia River Integrated Environmental Monitoring Program.

3. Key Indicator: Percentage of observation wells that show declining water levels due primarily to human activity

The percentage of observation wells with declining water levels due to human activities is a state or condition indicator. It addresses the question: Is more groundwater being used than can be sustained over time? This indicator is not a direct measure of volume of groundwater withdrawn, but uses changes in groundwater level due to human activity as a surrogate for changes in the supply of groundwater in aquifers due to human activity.

In some areas where available surface water supplies are already fully allocated, (e.g., parts of the Okanagan Valley), unavailable (e.g., some Gulf Islands), are too costly to develop, are of marginal quality, or require expensive treatment, groundwater is often a viable and cost-effective source of water supply. Industry, including manufacturing, mining and aquaculture, is the largest user of groundwater in British Columbia (approximately 55% by volume) followed by agriculture (approximately 20%) and municipalities (approximately 20%) (Berardinucci and Ronneseth 2002).

Water level measurements from observation wells show status and trends in groundwater resources with respect to water availability, replenishment, and use. Groundwater levels depend on recharge to, storage in, movement through, and discharge from an aquifer (aquifers are underground layers of rock and sand containing water). Groundwater storage in an aquifer is affected by the physical properties of the aquifer, such as porosity, thickness, and extent of the geologic deposit or rock comprising the aquifer. Recharge to and discharge from aquifers is affected by short and long-term changes in climate (precipitation and drought events), other natural phenomenon such as infiltration from or discharge to lakes and rivers, groundwater withdrawals, and land use activities. Water level fluctuations from human impacts include domestic and municipal withdrawal, irrigation (both withdrawal from and recharge to aquifers), deforestation, paving, alteration of wet lands, industry, and water impoundments.

This indicator shows only the proportion of observation wells that appear to have decreasing water levels as a result of human activities. It does not show wells that may be affected by human activities that may cause water levels to rise, such as return flow from irrigation practices or effluent disposal. Declining water levels related to human activities are mainly the result of local pumping for industry, agriculture, and municipal and private drinking water supplies.

The indicator is not intended to show whether there are long-term declines in groundwater level due to variations in climate. The main purpose of the observation well network is to monitor effects of pumping withdrawals and other human impacts (for indicators of climate change impacts, see the Climate Change paper in this report).

Methodology and Data

This indicator identifies sites with declining water levels due primarily to human activities by comparing trends in groundwater levels with the precipitation records for the same area. Wells with a pattern of water levels that differs from the pattern of natural climatic variation are likely to be affected by withdrawal of water for human activity. It follows the methodology used in previous reporting for this indicator (BCMOE 2002).

Data on water levels came from monitoring records of observation wells that are part of the British Columbia Observation Well Network. Precipitation data came from climate stations operated by Environment Canada for the area closest to each observation well.

Monthly hydrograph records of water levels were plotted for individual observation wells. The hydrograph trends were then compared to the cumulative precipitation departure (CPD) curves derived from the monthly precipitation data. Hydrographs that mirrored CPD curves were interpreted as reflecting natural seasonal variations. The remaining hydrographs were interpreted as showing impacts from human activity if they did not mirror CDP curves.

By focusing on comparing trends in water levels rather than the absolute water levels, the indicator minimizes two sources of variation.

- Natural seasonal and climatic variations in water levels. For example, there was below-average precipitation and groundwater levels between 1985 and 1990; therefore, water levels in observation wells also declined.
- Natural variation in groundwater levels among wells. Groundwater levels in some aquifers are at the land surface, or even above, in the case of flowing artesian conditions. In other aquifers, water levels may be tens of metres below ground level.

The hydrographs from all available observation wells were examined for each 5-year period (e.g., 2000–2005) to determine whether the overall trend in water level for that period was increasing, decreasing, or stable. Comparison with the CPD curves provided an indication of the degree and net effect of human impacts being observed over the time period examined. The number of wells showing decreasing water levels attributable to human impacts in each 5-year period were plotted as a percentage of the total number of wells monitored during that time. Note that some human activities, such a reduction in water withdrawals, could result in water levels recovering or rising.

Caveats:

- In most cases, it was necessary to make a subjective judgement of the trend in water level in a given well because there was no method to statistically determine trends.
- The time interval selected can affect the results. If the interval is too short, longer-term trends may not show up over short-term fluctuations. If the interval is too long, some trends may not be readily apparent.
- The cut-off date for each interval can affect the results. For example, whether a "peak" appears at the end or the middle of an interval will affect the results for that interval. To check this, for the analysis published in 2002, the trend analysis for each well was done for 5-year intervals shifted by 2 years (e.g., 1967–1972) and for a 7-year interval. Although the results were slightly different, the overall pattern was the same, which provides confidence that the method of analysis gave valid results.

- This indicator uses only change in water level, so wells with levels that drop during a 5-year interval then remain at the lower level will be recorded only as affected during the interval of the initial decline.
- The number of wells sampled varied each year and the spatial distribution of the wells in the network changed over time. This means that apparent trends may be, at least partly attributable to the change in number and location of wells sampled.
- The specific wells sampled have also changed over time as new wells were added to the network and existing wells were dropped from the active list. A list of active wells in the observation well network and the hydrographs for the individual wells are available on the Groundwater Observation Well Network website: *http://srmapps.gov.bc.ca/apps/gwl/disclaimerInit.do.*

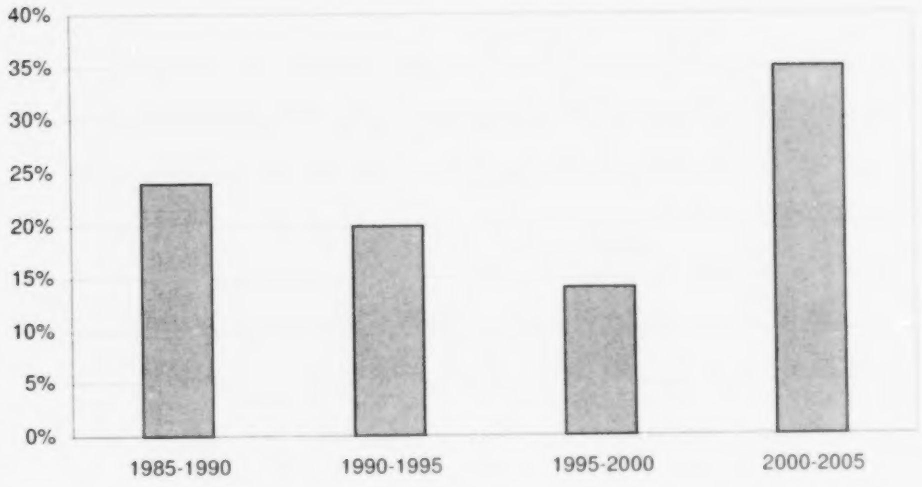
Table 7: Observation wells in B.C. that show evidence of human impacts, 2000–2005.

Years	Number of wells			
	Total	Showing natural fluctuations	Showing impact of human activities	
			with no water level decline*	with water level decline (% of total)
1985–1990	108	23	59	26 (24%)
1990–1995	125	28	72	25 (20%)
1995–2000	139	31	88	20 (14%)
2000–2005	127	50	33	44 (35%)

Source: Ministry of Environment 2007. Data from individual observation wells.

* Examples of human activities that can increase well levels: return flow from irrigation, effluent disposal.

Figure 4. Percentage of observation wells that show declining water levels due to human activities in B.C., 2000–2005.



Source: B.C. Ministry of Environment 2007.

The percentage of observation wells with declining water levels due primarily to human activities was 35% in 2000–2005 (44 of 127 sites with sufficient data) (Figure 4, Table 7). This was a large increase from 14% in 1995–2000. This increase may be attributed in part to enhanced monitoring activities in all heavily developed and highly vulnerable aquifers and areas of quantity concern since the late 1990s. One of the main purposes of the observation well network is to monitor the net effect of human impact (mainly pumping withdrawals); therefore, most observation wells are established close to these areas.

The data show that groundwater levels are not declining everywhere across the province, but rather in local areas where groundwater withdrawal and urban development have been intensive. Among the wells showing water level decline in 2000–2005, 17 (39%) are in the Vancouver Island-Gulf Islands region, 16 (36%) in the Okanagan region, 3 (7%) in the Interior Plateau (Williams Lake-Quesnel-Clinton region, 3 (7%) in the Kamloops-Merritt-Cache Creek areas, and 5 (11%) in five other regions of the province (1 observation well each in Whonnock, Tumbler Ridge, Powell River, Castlegar, and Salmon River).

Although specific information is not available on the quantities of groundwater being pumped, demand appears to have increased significantly in several areas of the province, possibly caused by renewed economic activity and construction of additional private and municipal wells.

4. Secondary Indicator: Number of heavily developed aquifers in B.C.

This is a pressure indicator, showing the current level of stress being placed on groundwater resources by human activities. Groundwater is often the only available or economical source of high quality, potable water for domestic use. Unregulated withdrawal of groundwater, however, can lead to high water use in some areas and lower groundwater levels, which presents a risk to both water supply and quality for nearby well owners. Outside of Victoria and Vancouver Island, groundwater supplies approximately 25% of the total municipal drinking water in the province (BCMOE 1994b). It is economically important to agricultural and industrial users. Groundwater is also an important source of water needed to maintain summer stream flows, which are critical for sustaining fish habitat and other aquatic life and the animals that depend on them.

Heavily developed aquifers are those where the extraction rate is high relative to the natural rate of recharge. Heavy demand puts the supply and quality of groundwater at risk. For example, excessive groundwater withdrawal in coastal areas can cause salt water intrusion into the aquifer. Although instances of water quality problems in local and regional aquifers occur, this is not a direct indicator of water quality in aquifers (see supplementary information, below).

Aquifers are a main source of water for drinking, crop irrigation, industrial processing (e.g., pulp mills) and, in some locations, aquaculture operations such as fish hatcheries. Much of the groundwater demand in British Columbia is from aquifers located near large urban centres and major agricultural areas. In addition, with recent efforts to explore alternative energy sources, groundwater is increasingly being used as a source of low-temperature geothermal energy for heating and cooling buildings.

Methodology and Data

The data for this indicator come from the aquifer inventory of British Columbia developed and maintained by the B.C. Ministry of Environment. The inventory contains 815 aquifers (as of March 2006), and since 2001, 377 aquifers have been added to the inventory. The ministry uses a classification system developed by Kreye et al. (1994) to classify aquifers according to level of development and vulnerability to contamination.

The level of development is determined through an assessment of demand on the aquifer relative to the productivity of the aquifer. Aquifers are categorized as high (I), moderate (II), or low (III) with respect to level of development.

Vulnerability to contamination is considered to be intrinsic to an aquifer. This means that it is based on hydrogeology alone and does not consider the existing type of land use or the nature of a potential contaminant. The vulnerability of an aquifer to contamination from surface sources is qualitative and assessed according to the type of aquifer, thickness and extent of geologic materials overlying the aquifer, depth to water or depth to the top of any confined aquifers, and the type and permeability of aquifer material (e.g., sand and gravel, fractured bedrock). Aquifers are categorized as high (A), moderate (B), or low (C) with respect to vulnerability.

Combining the two variables yields nine classes of aquifers, from IA (heavily developed with a high vulnerability to contamination) to IIIC (low development and low vulnerability). For more information about the aquifer classification system, see the guide by Berardinucci and Ronneseth (2002) available at *www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/aquifers/reports/aquifer_maps.pdf*.

In addition to the basic classification, the aquifer classification system includes a component in which each aquifer is assigned a value. The value is determined by summing the point values from hydrogeologic and water use criteria: productivity, size, vulnerability, demand, type of use, quality concerns (that have human health risk implications), and quantity concerns. The ranking value is used primarily to compare aquifers within a particular class. Each class has lower and higher ranked aquifers, and attention would be focussed on the higher ranked aquifers within the class. Ranking for specific aquifer class are available at: *http://aardvark.gov.bc.ca/apps/wells/jsp/common/aquifer_report.jsp*.

As of March 2006, 64 aquifers were designated as heavily developed (Table 8). Aquifers are found throughout the developed areas of British Columbia; 65% of the heavily developed aquifers are found on Vancouver Island, the Gulf Islands, and the Southern Interior. Although this is an increase from the 35 aquifers reported as heavily developed in 2001, it is not necessarily a negative trend. The increase is primarily the result of more aquifers having been identified and mapped as part of the provincial aquifer monitoring program.

Classifications of aquifers may change if there is a significant increase or decrease in groundwater extraction or an update of new information, such as boundary location. Some aquifers have been downgraded from moderate to heavily developed (e.g., Chemainus and Crofton on Vancouver Island) or upgraded from heavily to moderately developed (e.g., an unconfined aquifer at Rutland). As development increases, or future water quality issues arise, more changes will take place.

Table 8. Number and location of heavily developed aquifers in B.C., March 2006 (includes IA, IB, and IC aquifers).

Region (no. of aquifers)	Aquifers (1 each unless noted)	
Vancouver Island (21)	West Duncan	Thetis Island (2)
	Duncan	Saturna Island (2)
	Panorama Ridge – Chemainus	Mayne Island
	Chemainus and Crofton	North Gabriola Island
	Parksville	Scott Island
	Qualicum	Kolb Island
	Little Qualicum River Valley and Delta	Quadra Island (3)
	Hornby Island (Whaling Station Bay)	McCoy Lake, West of Port Alberni
	Norway Island	
Lower Mainland (12)	Vedder River Fan Aquifer	Green Lake (north of Whistler)
	Abbotsford-Sumas Aquifer	Alpha Lake (Whistler)
	South of Hopington	2 km West of Alpha Lake
	Hopington Aquifer	Gambier Island
	Langley/Brookswood Aquifer	South West Bowen Island (2)
	Belcarra	
Southern Interior (21)	Merritt Aquifer	Spallumacheen (S. of Armstrong)
	Grand Forks Aquifer	Lower Vernon Creek (between Okanagan Lake and Vernon)
	Cache Creek to Scottie Creek	Jim Smith Lake
	Cache Creek to Maiden Creek	East and North of Kelowna (3)
	Semlin Ranch Aquifer	Jaffray
	Sicamous (Mara Lake)	Cranbrook
	Osoyoos Lake to SW Tugulnuit	Wasa Lake
	North of Tuglunuit to Vaseux Lk	Cherry Valley – Kamloops
	District of Lake Country	Clearwater
	Kalamalka Lake to Vernon	
Northern Interior (10)	Lower Nechako River Aquifer	Dog Creek Rd, S. of Williams Lake
	Red Bluff (Quesnel)	Williston Lake (Mackenzie)
	Williams Lake Aquifer	Morfee Lakes (MacKenzie)
	Hill Southwest of Williams Lake	Gerow island Burns Lake
	West of Dragon Lake	North shore Burns Lake

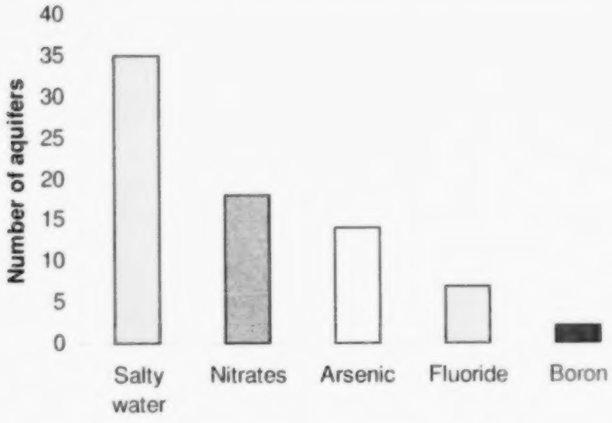
Source: B.C. Ministry of Environment, Science and Information Branch, Watershed and Aquifer Science Section, 2007.

Supplementary Information: Aquifers at risk in B.C.

The aquifer inventory maintained by the B.C. Ministry of Environment identifies aquifers that are vulnerable to contamination and those with documented groundwater quality concerns (c.f. BCMOE 1994a). The most common water quality problem in B.C. aquifers is salty water, followed by nitrate contamination (Figure 5).

Vulnerability, as defined by the aquifer classification system used by the B.C. Ministry of Environment (see Kreye et al. 1994), refers to the intrinsic vulnerability of the aquifer, irrespective of the type and intensity of human activities above it. An aquifer is considered vulnerable to contamination if it is "unconfined" (not overlain by a clay, till or hardpan layer) and if the water table is shallow.

Figure 5. Common water quality problems affecting aquifers in B.C., 2007.



Source: B.C. Ministry of Environment, Groundwater and Aquifer Science Section. 2007.

Note: Figure shows dominant concern; aquifers may have more than one water quality problem.

A count of current aquifers classified as IA (heavily developed with high vulnerability to contamination) and those with water quality concerns documented in Ministry of Environment Watershed and Aquifer Science files at the time the aquifer was classified, showed that of 815 aquifers in the inventory:

28 aquifers are considered heavily developed and highly vulnerable to contamination. Many of these supply drinking water to large communities, such as Langley, Abbotsford, and Prince George (Table 9).

- 53 aquifers have documented health quality concerns (Table 10). Most of these are in the Southern Interior, on the Gulf Islands, the east coast of Vancouver Island, and the Lower Mainland. Thirty-five aquifers reported elevated saline levels, often the result of excessive groundwater withdrawals in coastal regions that causes sea water intrusion into the aquifer. Twelve aquifers, primarily in the Peace River area, also reported very hard water that was unsuitable for drinking water without further treatment.
- 27 of the heavily developed aquifers also have a documented quality or quantity concern (or both) (Figure 6). This is based on files available at the time the aquifer was classified. Other aquifers may also have such concerns, but the information was not available at the time the aquifer was classified.

Although the number of heavily developed, highly vulnerable aquifers and aquifers with reported health concerns has increased over the 18 aquifers identified in 2001, the increase is primarily the result of more aquifers being identified and mapped since then.

The greatest number of aquifers with reported water quality concerns, or those most at risk (classed as IA), are associated with high levels of human settlement. However, health-related water quality concerns have been reported in both heavily developed aquifers and in other vulnerable aquifers that are not heavily developed.

Table 9. Heavily developed aquifers vulnerable to contamination (classified as IA in B.C. Ministry of Environment aquifer inventory as of March 2006).

Region (no. of aquifers)	Aquifer	
Lower Mainland (6)	Vedder River Fan	Langley/Brookswood
	Abbotsford-Sumas	Belcarra
	Hopington	Green Lake (Whistler)
Vancouver Island (9)	Duncan	North Gabriola Island
	Chemainus and Crofton	Thetis Island (2)
	Whaling Station Bay (Hornby Is.)	East Saturna Island
	Little Qualicum R. valley and delta	Kolb Island
Southern interior (10)	Grand Forks	Spallumacheen (South of Armstrong)
	Merritt	Kalamalka Lake to Vernon
	Cache Creek	Jaffray
	Osoyoos Lake to SW Tugulnuit Lake	Wasa
	North of Tugulnuit Lake to Vaseux Lake	Clearwater
Northern Interior (3)	Lower Nechako	Morfee Lakes (Mackenzie)
	Red Bluff	

Source: Ministry of Environment, Science and Information Branch, Watershed and Aquifer Science Section 2007.

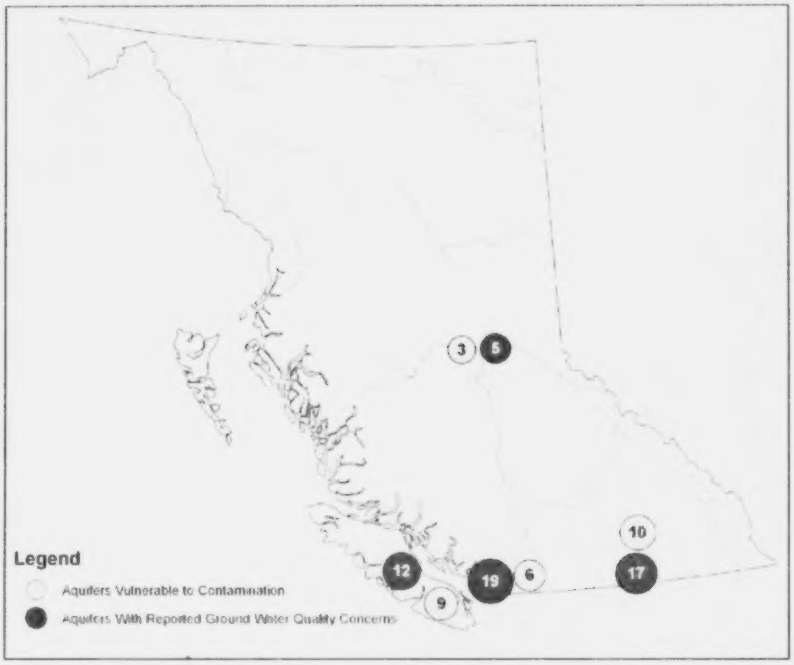
Table 10. Aquifers with reported groundwater quality concerns (as of March 2006).

Regions (no. of aquifers)	Aquifer	
Lower Mainland (19)	Abbotsford-Sumas Aquifer	McMillan Island
	Mount Lehman	Columbia Valley Aquifer
	Grant Hill Bedrock Aquifer	Coquitlam River Floodplain
	Aldergrove	Gambier Island (2)
	Hopington	Sechelt (2)
	Langley/Brookswood	Halfmoon Bay
	Boundary Avenue near Border	Mixel Lake
	South of Hopington	Kleindale
		Bowen Island
Vancouver Island (12)	Scotch Creek	Comox Harbour to Merville
	Cedar, Yellow Point, North Oyster	Port Renfrew
	Mayne Island (2)	Colwood, Langford, Metchosin
	Keats Island	North shore Sproat Lake
	East Saanich Peninsula	McCoy Lake, Port Alberni
		Saturna Island
Southern Interior (17)	Merritt Aquifer	Lower South Thompson
	Grand Forks Aquifer	Osoyoos Lake to southwest Tugulnuit Lk
	Osoyoos West Aquifer	North of Tugulnuit Lake to Vaseux Lake
	Osoyoos East Aquifer	Mouth of Trout Creek (Summerland)
	Osoyoos East Confined Aquifer	Cranbrook
	Scotch Creek	St. Mary River
	Meyers Flat	Deadman Valley
	Marron Valley	
	Oyama	
	Deep Creek (North of Armstrong)	
Northern Interior (5)	Northeast of Quesnel	Taylor Flats
	108 Mile Limestone Aquifer	Fort St. James
	Progress	

Source: Ministry of Environment, Science and Information Branch, Watershed and Aquifer Science Section 2007.

Note: Water quality concerns were documented when records were entered into the provincial aquifer inventory; the present water quality status of aquifers may differ.

Figure 6. Aquifers vulnerable to contamination and with reported groundwater quality concerns.


3
5
10
12
19
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17
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Legend
○ Aquifers Vulnerable to Contamination
● Aquifers With Reported Ground Water Quality Concerns

Source: Ministry of Environment, Science and Information Branch, Watershed and Aquifer Science Section 2007.

5. Secondary Indicator: Daily municipal water use per capita in B.C.

The average daily consumption of municipal water per capita is a pressure indicator. It shows the demand that municipal water use is placing on British Columbia's supply of fresh water. This indicator addresses the question: What are the trends in individual water use in B.C.? Municipal water use includes water used for residential (domestic), industrial, commercial, and other uses. Residential water use is only a portion of municipal water use, accounting for about half of municipal water use nationally.

Current water use patterns in British Columbia can have environmental and economic consequences, including seasonal water shortages. Excessive water use can draw down natural water flow levels and reduce the natural ability of aquatic ecosystems to deal with pollutants. Increased water use also dilutes wastewater, reducing wastewater treatment efficiency and effluent quality. Excessive water use increases the cost of providing drinking water treatment and supply infrastructure.

Methodology and Data

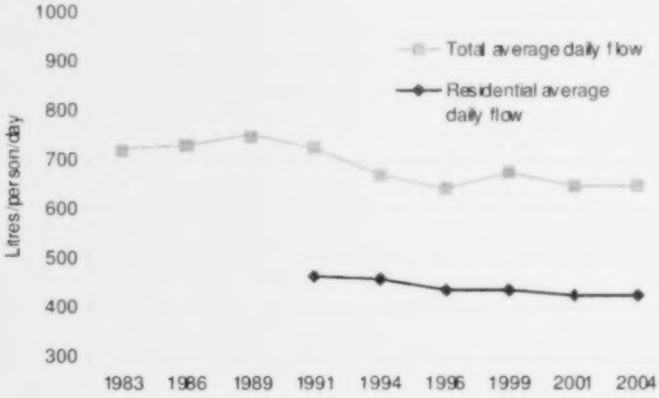
The Municipal Water and Wastewater Survey (MWWS) of Environment Canada collects water and sewage data for municipalities at 5-year intervals. Before 2001, the survey (formerly the Municipal Water Use and Pricing Survey or MUD) was restricted to communities with a population of 1,000 or higher. In 2001, the methodology was changed to include a representative sample of 660 communities with fewer than 1,000 residents each. However, for the summary information shown in this indicator, these data were excluded in order to allow comparison with MUD data from earlier years. In 2004, 777 communities responded completely or almost so, down from the 880 communities in 2001. This is a relatively low response rate and the survey responses were supplemented with call-backs to large municipalities for additional or missing information. Values for some missing data were calculated, based on previous years' data after adjusting for population changes over time. This brings the effective response rate up to 1,418 municipalities, representing 28.9 million Canadians (Environment Canada 2007b).

The MWWS data used for this indicator were:

- Average daily flow (ADF): This is the water reported as used by a municipality. The total ADF is the sum of all water used, including residential, industrial, commercial, and other purposes (the latter includes losses). The residential ADF is an estimate of residential use, separate from commercial, industrial and 'other' purposes.
- Municipal population served water: This is the population in the municipality served by any water system. MWWS uses Statistics Canada population estimates for census and non-census years where possible. It does not include populations external to the municipality.

The figures for water use per person in B.C. (Figure 7, Table 11) were calculated by totalling the average daily flow (in cubic metres per day; 1 m^3 = 1,000 litres) and dividing it by the total municipal population served water. Previous environmental trends reports have reported only the total ADF, divided by population, to arrive at per capita figures; therefore, these are included in this report (Table 11). The estimated residential ADF per capita is also reported because per capita estimates actually apply only to residential use rather than commercial or industrial use.

Figure 7. Per capita municipal water use in B.C., 1983–2004. Total average daily flow used by municipalities and estimate of residential component.



Source: Environment Canada, Municipal Water Use Database, and Municipal Water and Wastewater Survey database.

Table 11. Per capita municipal water use in B.C., 1983–2004.

Year	Total average daily flow (litres/person/day)	Average daily residential flow (litres/person/day)
1983	722	–
1986	732	–
1989	752	–
1991	726	465
1994	672	459
1996	642	440
1999	678	439
2001	651	425
2004	649	426

Source: Environment Canada, Municipal Water Use Database and Municipal Water and Wastewater Survey database.

Note: Residential average daily flow is reported separately and is also included in the total average daily flow.

MUD and MWWS survey records show an overall decrease in the municipal water use per capita since 1983. One factor contributing to the decline in residential water use may be the introduction of education and incentive programs to improve water conservation. Over the last decade, municipalities and regional districts in B.C., have been increasing efforts to inform the public about water conservation through workshops and public advertising. The Greater Vancouver Regional District and Capital Regional District have also offered cash rebate incentive programs to replace older equipment such as toilets, washing machines, or irrigation equipment with more efficient models, and most municipalities have instituted restrictions on summer water use. Programs for businesses include an incentive rebate to replace water-cooled equipment, water audit programs, and education materials for hotel guests.

The total ADF and residential ADF per capita for B.C. continues to be above the national average (Table 12). In 2004, the total ADF was 609 litres per person in Canada, while in B.C. it was 649 litres per person; residential ADF was 329 litres per capita nationally, while in B.C. it was 426 litres (Environment Canada 2007a). The higher rate of water consumption in British Columbia may be a result of the flat rate pricing systems still in use in most B.C. municipalities. Users with water meters pay according to volume of water used, while those without metering pay a flat rate for generally unlimited access to water services. B.C. has the largest population with flat rate pricing systems of all provinces and is one of the provinces with the lowest proportion of residential users having water meters. Although the percentage of the municipal population in B.C. with water meters increased from 22% in 1991 to 30% in 2004, the majority of British Columbians (70%) still pay a flat rate for water service (Environment Canada 2007a).

Table 12. Municipal water use in Canada, per capita, 2004.

Province / Territory	Total average daily flow (litres/person/day)	Residential average daily flow (litres/person/day)
Newfoundland & Labrador	780	501
PEI	569	238
Nova Scotia	546	321
New Brunswick	1384	438
Quebec	848	424
Ontario	481	260
Manitoba	466	219
Saskatchewan	516	303
Alberta	488	271
B.C.	649	426
Yukon	932	645
NWT	437	257
Nunavut	134	113
National Average	609	329

Source: Environment Canada 2007b: Municipal Water and Wastewater Survey 2004 Summary Tables. *www.ec.gc.ca/water/MWWS/pdf/MWWS_2004_Tables_En.pdf*.

Table 13 shows how B.C. and Canada compare to other developed countries in residential/domestic water consumption per capita. Definitions and estimation methods employed by these countries vary considerably and change over time, making water use comparison difficult, therefore these figures are presented as a rough comparison only. B.C. has a higher domestic consumption rate than all of the countries listed in the table, well above the worst performer (the United States) and four times higher than the estimated domestic water use from the lowest consuming countries.

Table 13. Domestic water use per capita for selected countries.

Country	Domestic water use (litres/person/day)
British Columbia	426*
United States	380
Canada	335*
Italy	250
United Kingdom	200
Sweden	200
France	150
Israel	135

*Source: Environment Canada. 2004. Water Use: Residential average daily flow per capita. Other data: Environment Canada. Freshwater website *www.ec.gc.ca/water/images/manage/use/a4f4e.htm*.

WHAT IS HAPPENING IN THE ENVIRONMENT?

The overall quality of most surface water bodies monitored in B.C. is good or stable, and most of the mapped aquifers in the province are not heavily developed. However, the indicators in this paper show that the fresh water resources, including surface water and groundwater, in British Columbia are under pressure from increasing human population and economic activity.

- According to the national standard Water Quality Index more than half of monitoring stations in B.C. are in good or excellent condition; 39% of stations are in fair condition, only 10% are marginal, and none are in poor condition. Because most monitoring stations are located where there is a risk of pollution from industrial discharge, mining, forestry, or other human activities that can affect water quality, is likely that a much greater proportion of the thousands of other B.C. water bodies are actually in good or excellent condition.
- Trends in surface water quality, for monitoring stations largely located in areas of greatest human impacts, showed 13 stations with improving trends, 18 with stable trends, and 4 with deteriorating trends. Three other stations had mixed trends.
- An increasing proportion of observation wells show a trend of decreasing in water levels as a result of impacts from human activity. For the 5-year period up to 2005, 35% of the wells showed a trend of declining in water levels that was not correlated with natural variations in precipitation. This increase over previous years may be a result of increased monitoring in

the most heavily developed and vulnerable aquifers and in areas where there are currently concerns about water supply.

- As of March 2006, records from the provincial aquifer monitoring program show 64 heavily developed aquifers of the 815 aquifers mapped. This was up from the 35 heavily developed aquifers recorded in 2001, mainly because more resources have been allocated to identifying and mapping aquifers in the intervening years. There are 27 heavily developed aquifers with documented water quality problems, such as salt water intrusion and very hard water, that make them unsuitable for drinking water.
- Water use patterns in B.C. show a decrease in the estimated residential water use per person from 465 litres/person/day in 1991 to 426 litres in 2004. This continues to be above the Canadian national average of 329, putting B.C. in the top bracket of water-using provinces.

Protecting drinking water quality and maintaining the integrity of aquatic ecosystems are important environmental issues. Ongoing monitoring, protection, and careful management of these water resources are of critical importance. British Columbia has an abundance of surface water in lakes and streams compared to other parts of the world, but increasing population and economic activity in the province is escalating the pressure on water supplies, both from pollution and from withdrawals of water. As the provincial population continues to grow and demands on groundwater supplies increase, there is a corresponding need to protect and manage the resource.

WHAT IS BEING DONE ABOUT IT?

Federal-Provincial Initiatives

Canadian Council of Ministers of the Environment Water Quality Initiatives: The federal government works with the provinces and territories to develop national, science-based, voluntary guidelines for water quality (*www.ec.gc.ca/CEQG-RCQE/English/Ceqg/Water/default.cfm*). The provinces and territories use these guidelines when creating their own enforceable standards, objectives, or guidelines. British Columbia is part of the federal-provincial CCME initiative to improve the national Water Quality Index and water quality guidelines, and to develop larger and more representative water monitoring networks. Reported through CCME but developed through the Federal-Provincial-Territorial Committee on Drinking Water, the Canadian Drinking Water Quality Guidelines establish maximum acceptable concentrations for substances in water used for drinking (*www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/index_e.html*). To date, guidelines have been established for more than 85 physical, chemical, and biological attributes of water quality. Other water quality guidelines have been produced for aquatic life, wildlife, agriculture, and recreational uses.

CCME is currently developing a national strategy for municipal effluents to ensure that consistent levels of treatment are provided across Canada. This strategy also includes the requirement to meet effluent objectives developed from the national CCME water quality guidelines.

Federal-provincial reporting: Environment Canada and the provinces and territories work together to produce annual reports on national water quality. Reports based on protection of aquatic life were released in 2005 and 2006 and will continue until 2009. A recent example: The British Columbia and Yukon Territory Water Quality Report 2001–2004 (Environment Canada et al. 2007) *www.env.gov.bc.ca/wat/wq/bcyt_wqrep_01_04/bcytwqrep_01_04.pdf.*

Provincial Government Regulations and Initiatives

In addition to current work on developing a provincial water action plan (c.f., BCMOE 2007), many other provincial government regulations, monitoring, and educational activities support stewardship of water resources in British Columbia.

BC Drinking Water Protection Act: In 2002, the provincial government published an Action Plan for Safe Drinking Water in British Columbia. (*www.healthservices.gov.bc.ca/cpa/publications/safe_drinking_printcopy.pdf*)

As part of the plan, the government has improved drinking water source protection through the *Drinking Water Protection Act* (2001) and the amended Regulation (2005) *www.qp.gov.bc.ca/statreg/reg/D/200_2003.htm*. The Act generally covers all water systems other than single family dwellings. It outlines requirements for water suppliers to ensure that water supplied to their users is potable and meets any additional requirements established by the Drinking Water Protection Regulation. It has provisions for Drinking Water Protection Plans, which are regulatory plans that may be done where there are demonstrated risks to human health from drinking water (none had been completed as of June 2007). Provincial reports on drinking water protection are available at *www.health.gov.bc.ca/protect/dwpublications.html.*

BC Water Act and Groundwater Protection Regulation: In British Columbia the allocation of water is regulated under the Water Act. The Act authorizes the licensing of diversion, storage, and use of water from streams, lakes, and springs; it regulates works that may be constructed, and requires changes in and about a stream to be approved. The province is currently involved in seeking consensus on a new water allocation model and modifying and streamlining the Water Act and related legislation.

Although groundwater withdrawals are not regulated under the *Water Act*, the Ground Water Protection Regulation (2005) introduced standards for well construction and management to protect the resource. Phase 2 of the Ground Water Protection Regulation is being developed and will include additional standards for wells and well pumps, requirements for siting, testing, and reporting of wells, and controlling artesian flow.

BC Water Management Plans: In 2004, Part 4 of the *B.C. Water Act* came into force to allow some aspects of water management to be addressed through water management plans. These are area-based plans that address or prevent risks to water quality, conflicts between users, and between users and instream uses. The plans can apply to both surface water and groundwater. The Minister of Environment initiates the plan, which is developed in accordance with terms of reference through stakeholder and public consultation. Once complete, the plan is submitted to the Minister of Environment, then to the provincial Cabinet for approval.

Approved plans are legally enforceable. An approved water management plan is implemented by regulation and may restrict activities such as well drilling, and have an impact on decisions made under other legislation, including zoning bylaws. Plans would only be developed in critical areas when other regulatory and non-regulatory approaches have not successfully addressed water resource problems.

A pilot Water Management Plan under the provisions of Part 4 of the *Water Act* is being developed in the rapidly growing Township of Langley. The area is characterized by a mix of urban and rural land use that is heavily dependent on groundwater supplies for agricultural, domestic, commercial, and industrial uses. About half of the municipal water supply and all of the rural supply comes from groundwater. Monitoring shows that groundwater levels in intensively used aquifers are declining, primarily due to over-extraction of groundwater. There have also been local occurrences of poor water quality due to nitrates, arsenic, coliforms, iron, and manganese.

In 2002, the Township of Langley adopted a Water Resource Management Strategy to ensure safe drinking water, maintain adequate water supplies, and protect environmental values such as fish habitat. It is anticipated that the Langley plan will be completed by December 2007. If approved by Cabinet, implementation and compliance strategies will be developed in 2008/09.

BC Hydro Water Use Plans (WUPs): In 1996, the B.C. government created a new water use planning process as part of licensing under the *B.C. Water Act* for BC Hydro's hydroelectric power and other water control facilities. WUPs take into account multiple uses for the resource as well as social and environmental values. As much as possible, the goal of the process is to achieve consensus on a set of detailed operating rules for each dam or other facility that satisfies the range of water use interests at stake. WUPs are prepared through a collaborative effort involving the licensee, government agencies, First Nations, other key interested parties, and the general public. They are developed to balance the range of interests, such as fish and aquatic habitat, power generation, flood control, and in some cases, recreation and heritage resources. WUPs specify the operating conditions relating to water licences issued under the Water Act. A WUP is implemented by an order of the Comptroller of Water Rights.

As of 2007, 23 BC Hydro Water Use Plans have been developed. Of these, 18 plans have been implemented, and approval for the remaining 5 plans is expected by the end of 2007.

More information is available at *www.env.gov.bc.ca/wsd/plan_protect_sustain/water_use_planning/index.html*.

B.C. Ministry of Environment initiatives: Responsibility for monitoring water resources and supporting stewardship of water resources rests with this ministry in the provincial government. The ministry:

- Increased funding for water quality monitoring to be undertaken under the Federal-Provincial Water Quality Monitoring Agreement. Funds are going toward drilling additional groundwater observation wells and modernizing data collection techniques, including transfer of real-time data using telemetry.

- Signed a Memorandum of Understanding with Natural Resources Canada to conduct regional groundwater assessments in BC. Assessments of regional aquifers is currently taking place in the Okanagan Basin.
- Is in the process of reviewing the Observation Well Network. A review was completed for Okanagan Basin and staff are currently implementing recommendations to enhance monitoring. Reviews of the Observation Well Network will be conducted in other areas of the province on a priority basis.
- Is creating a toolkit to support decision-making in areas affected by the mountain pine beetle infestation, in collaboration with the Ministry of Forests and Range. Changes in water flows, stream temperature, sedimentation, and other factors in beetle-killed forests affect water resources for people and wildlife dependent on aquatic ecosystems. The tool kit is for use by industry, government, First Nations, and communities as they make decisions around salvage activities, restoration planning, and community preparedness.
- **B.C. Water Conservation (Plumbing) Regulation**: In 2005, a revised Plumbing Regulation took effect that requires all new toilets installed in areas of the province specified in the regulation must be 6-litre, low-consumption models. The regulation applies to 39 geographic areas, including the populated areas of Vancouver Island (such as the Capital, Cowichan Valley, and Nanaimo regional districts), Lower Mainland (Metro Vancouver, Gibsons), and the more populated areas of the central interior. In areas not specified for low-consumption toilets, the regulation requires that new installations use fixtures with flush cycles no greater than 13.25 litres. More information at *www.housing.gov.bc.ca/building/Low_Consumption_Toilets.htm.*

Other Water Sustainability Initiatives in BC

Water Sustainability Action Plan (WSAP) for British Columbia: This plan was introduced in 2004 and is a key initiative to improve awareness, build capacity, and encourage action around the sustainable use of water resources and water stewardship in British Columbia. (See *www.waterbucket.ca/waterbucket/dynamicImages/386_WaterSustainabilityActionPlanforBC.pdf*)

The WSAP is coordinated and delivered by the Water Sustainability Committee, a partnership of government and non-government organizations chaired by the British Columbia Water and Waste Association. The WSAP promotes integrated "water-centric" planning at all levels through six interconnected programs: the WaterBucket website Partnership; the Water$ave Tool Kit for British Columbia; Convening for Action – Roundtables on Water Sustainability; the Green Infrastructure Partnership; the Water Balance Model for British Columbia; and Watershed/Landscape-Based Approaches to Community Planning. Accomplishments to date include the following:

- The WaterBucket website (*www.waterbucket.ca/*). Launched in 2005, this website is a key communication tool for the Water Sustainability Action Plan. It provides a 'one-stop' portal to a comprehensive set of information resources and planning tools. Among other goals, the website is intended to address concerns of many water suppliers and managers in B.C. over future limits to water supply, given population growth and drought conditions experienced in recent years. The website now has seven communities-of-interest: Water-Centric Planning;

Water Use and Conservation; Rainwater Management; Green Infrastructure; Agriculture and Water; Convening for Action; and Small Community Infrastructure Sustainability.

- The Water Balance Model for British Columbia. This is a web-based evaluation tool that quantifies the benefits of installing rainwater source controls such as green roofs, rain gardens, and infiltration facilities under different combinations of land use, soil type, and climate conditions. Early success in British Columbia led to the decision in 2004 to create a national Water Balance Model for Canada at *www.waterbalance.ca*.
- The Water$ave Tool Kit for BC. This resource has posted more than 50 province-wide success stories in the Water Use and Conservation Community-of-Interest pages on the Waterbucket website.
- Convening for Action pilot programs in the South Okanagan, Vancouver Island and Metro Vancouver promoting "water balance/water centric" approaches to rainwater management for community planning and land development. Experience from these pilot programs will be used to draft a provincial Water-Centric Planning Guidebook.
- Green Infrastructure Partnership workshops in 2004 and 2005 promoted the benefits of a "design with nature" approach to sustainable community planning and land development.

Local Planning: Beyond water planning processes done under a regulatory framework, there are a variety of locally led initiatives under way in BC. These planning initiatives are led by local government or an interest group to address specific problems with water quantity or quality. The success of such non-regulatory plans depends on how well all parties adhere to the voluntary plan recommendations. Some examples include:

- In the Okanagan, several processes have been undertaken to address the issue of community water supply and fisheries conflicts. Locally led water plans have been developed for Trout Creek, Trepanier Creek, and one is underway for Mission Creek. An extensive study of water supply and use is being undertaken for the Okanagan Basin *www.obwb.ca/water_supply_demand/*.
- On Vancouver Island a plan has been developed for the Cowichan Basin (Cowichan Basin Water Management Plan, *www.cvrd.bc.ca/water_cowichan/index.htm*). Initially driven by fisheries interests, this plan has expanded to include more issues and is now being championed by the regional district as a tool to help guide future growth. Campbell River also has developed a plan for the community watershed.
- Other examples are the Nicola Water Use Management Plan to address water supply management for fish, as well as agricultural water use conflicts, and the City of Chilliwack groundwater protection plan (*www.chilliwack.com/main/page.cfm?id=205*).

The Water Sustainability Project (WSP): This project began in January 2003 at the University of Victoria POLIS Project on Ecological Governance. The focus of the WSP is to provide an understanding of the dynamics of urban water use and to promote demand management and ecological governance as part of the broader goal of sustainable water management. The project has produced detailed studies of water use in Canada, and developed a comprehensive legal and policy framework for urban water management and action plans for federal, provincial, and municipal governments. A key objective is increasing public awareness around the importance and limits of water in Canada. (*www.waterdsm.org/index.htm*)

WHAT YOU CAN DO

Individuals can take many small and large actions to protect surface water from pollution and reduce the amount of water used from aquifers and other sources.

Ways to protect water quality:

- Reduce your use of household hazardous products (cleaning products, pesticides, solvents, etc.) and use less harmful alternatives, such as phosphate-free soaps and detergents.
- Never dispose of such products where they can enter storm drains. If possible, take them to recycling or collection centres. For locations see the Recycling Council of B.C. *www.rcbc.bc.ca/* or call: 1-800-667-4321.
- Regularly check and repair fluid leaks from your vehicle. If you service a vehicle yourself, be sure to recycle used oil and antifreeze.
- Reduce or eliminate use of fertilizers and pesticides on your lawn and garden. Use slow-release fertilizers, non-persistent pesticides, and natural pest control products instead.
- Compost your kitchen waste and other organic matter and recycle the compost to gardens.
- For onsite sewage systems, septic tanks should be inspected and pumped out every 3 to 5 years. Don't put toxic chemicals or solids down the drain (i.e., avoid garbage disposal units). Keep vehicle traffic and heavy objects off your septic field. If the field is covered with a lawn, avoid overwatering.

Conserve water indoors:

- Install low-flow toilets (save 6 to 14 litres per flush) or install water displacement devices in toilets.
- Install low-flow showerheads and faucets.
- Check all taps and fixtures for leaks.
- Take shorter showers or use less water in baths.
- Run dishwashers only when full, rather than wasting water on a partial load.
- Use short cycles and full loads in washing machines.
- Purchase water-conserving washing machines and dishwashers when it is time to replace appliances.

Conserve water outdoors:

- Make sure watering systems do not leak.
- Let lawns go dormant in the summer, watering only once in months with no rain.
- Water in the morning or evening to reduce loss to evaporation.
- Use drip irrigation systems for garden plants and be careful not to over-water.
- Choose drought-tolerant plants; group plants with the same water needs together.

- Keep soil around plants covered with leaves or other organic mulch.
- Use a bucket of soapy water to wash your car, then rinse quickly using a hose.
- Sweep sidewalks and driveways rather that using water to spray them clean.

Check your regional district for information on rebate and incentive programs and other local information:

- Greater Vancouver Water District Water Conservation programs and information are available at *www.gvrd.bc.ca/water/conservation.htm*. This site includes information on how to conserve water, check for leaks, choose models of low-flush toilets and other fixtures, rebate and incentive programs, and provides tips for conserving water (GVRD 2006) *www.gvrd.bc.ca/water/pdfs/WaterConservationTips.pdf*.
- Capital Regional District Water Conservation programs and information are available at *www.crd.bc.ca/water/conservation/*. This site includes information on how to conserve water, and on rebates and incentive programs for residential users and businesses.

Participate in community efforts:

- Join or form a community stewardship group to care for a local water body. For watershed groups near you, see *http://stewardshipcanada.ca or http://waterquality.ec.gc.ca*.
- Participate in local community planning and regional growth strategies.
- Encourage your neighbours, local employers, and community leaders to implement water quality protection measures.

More Information

Environment Canada has a comprehensive website with information on what individuals can do to protect water resources, conserve energy, and take other steps to protect the environment. Separate webpages provide information on activities at home, work, school, on the road, and for recreation (cottages, boating, etc.). See *www.ec.gc.ca/eco/main_e.htm*.

The Canada-British Columbia Farm Planning Program has produced an Environmental Farm Planning Reference Guide for stewardship on farms and ranches, including a section on protecting water resources. See *www.agf.gov.bc.ca/resmgmt/EnviroFarmPlanning/EFP_Refguide/refguide_toc.htm*.

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Climate Change

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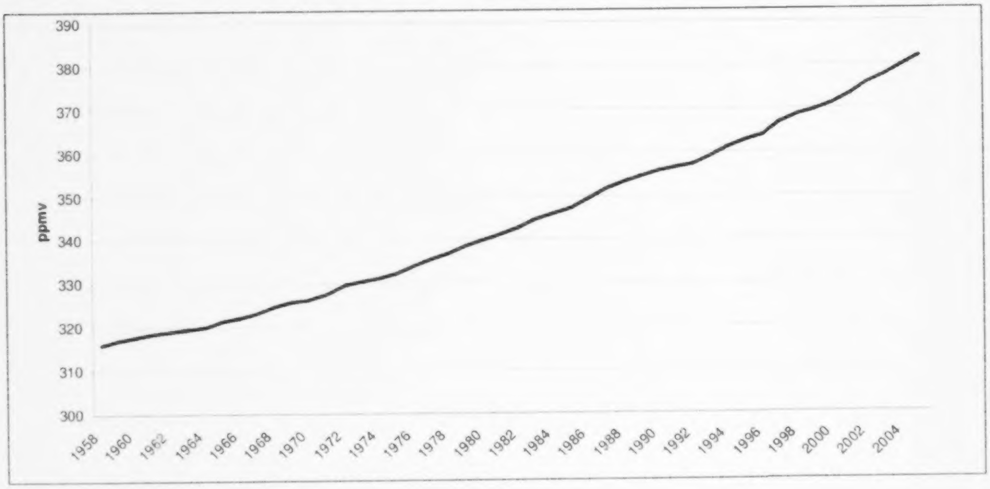
Climate Change

BACKGROUND

The most recent assessment of global climate change from the International Panel on Climate Change (IPCC) concludes with a high degree of certainty that Earth's atmosphere is warming and that the main cause is the build-up of greenhouse gases in the atmosphere from human activity. The IPCC is the authoritative international body set up by the United Nations in 1988 to review scientific information on climate change. It involves over 2,000 of the world's climate experts, who survey the worldwide technical and scientific literature and periodically publish assessment reports. The fourth, and most recent assessment, was released in 2007.

Greenhouse gases include atmospheric gases such as carbon dioxide (CO_2), methane, and nitrous oxide, and some human-created compounds. These gases are released into the atmosphere by fossil fuel combustion, deforestation, agriculture, and industrial activity, as well as through naturally occurring processes. The gases trap solar energy, which warms the atmosphere and the surface of the Earth. As the levels of these gases build up in the atmosphere, they trap more heat energy. As the atmosphere warms, the temperature of air, land, and water also warms, which in turn affects patterns of precipitation, evaporation, wind, and storms, as well as ocean temperature and currents.

Figure 1. Carbon dioxide concentrations in Earth's atmosphere recorded at Mauna Loa, Hawaii (1958–2006) (in parts per million by volume, ppmv).



Sources: Data through 2004 from *http://cdiac.ornl.gov/ftp/trends/co2/maunaloa.co2*; data for 2005, 2006 from *www.cmdl.noaa.gov/projects/web/trends/co2_mm_mlo.dat*.

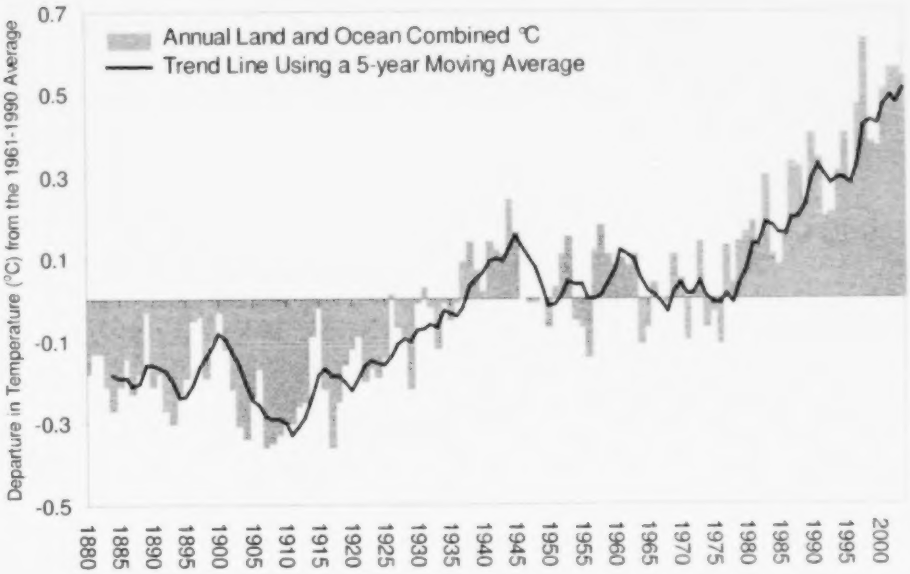
Since 1958 the observatory at Mauna Loa, in Hawaii, has been monitoring carbon dioxide concentration in the atmosphere. This is the longest continuous and accurate record of CO_2 in the world. Figure 1 shows that the average level of carbon dioxide, an important greenhouse gas, has been steadily increasing. In 2006 it reached 382 parts per million by volume (ppmv). Studies on air trapped in dated ice cores have shown that the concentration of CO_2 before the industrial era was about 280 ppmv. This means that the atmospheric CO_2 concentration has risen 42% over what it was about 260 years ago.

Concentrations of other greenhouse gases have been rising as well, notably methane and nitrous oxide. All greenhouse gases added together have the warming equivalent of about 430 ppm CO_2 (CO_2 equivalent or CO_2e is used to make comparisons between gases). The most recent IPCC report states that the increase in CO_2 has been due primarily to fossil fuel use with a smaller input from land-use change, whereas the increases in methane and nitrous oxide have been caused primarily by agriculture (IPCC 2007a).

As greenhouse gas concentrations in the atmosphere increase, global temperatures also rise as more of the incoming energy (solar radiation) from the sun is trapped by the atmosphere. Records show that global temperatures, averaged world-wide over the land and sea, rose 0.74 ± 0.18°C in the 100 years between 1906 and 2005 (IPCC 2007a) (see Figure 2). The average global air temperature increased almost twice as fast in the last 50 years as it did in the last hundred years, showing that the rate of change is increasing (IPCC 2007a). Globally, 11 of the 12 warmest years since 1850 occurred between 1995 and 2006. Cold days, cold nights, and frost have become less frequent, while hot days and nights and heat waves have become more common (Solomon et al. 2007).

The Earth is not warming evenly, however, and some parts, particularly northern latitudes, have been warming more rapidly than equatorial regions. As remote as they are, the polar regions have been most obviously affected so far by climate change. The average temperature in the Arctic is increasing twice as quickly as the global average (IPCC 2007a). The extent of sea ice, which was relatively stable until the 1960s, has been shrinking at the rate of 7.8% per decade since then (Stroeve et al. 2007). Arctic sea ice coverage in April 2007 was the lowest for that month since satellite imagery of the northern ocean began in 1979. The US National Center for Atmospheric Research projects that the Arctic Ocean will be almost free of ice in the late summer by 2040 (Holland et al. 2006). Farther south, the ground is thawing at sites near the southern margin of permafrost in northern Manitoba. The thawed ground no longer provides a good support for trees, which are being replaced by floating mats of sedge and moss (Camill 2005). A preliminary model showed that 60% of Canada's permafrost could be gone by 2100 (Lawrence and Slater 2005).

Figure 2. Annual global land temperature and ocean temperature (°C) relative to the average temperatures for 1961–1990.



Source: National Oceanic and Atmosphere Administration (NOAA)
http://lwf.ncdc.noaa.gov/oa/climate/research/anomalies/anomalies.html#anomalies.

Impacts of Climate Change

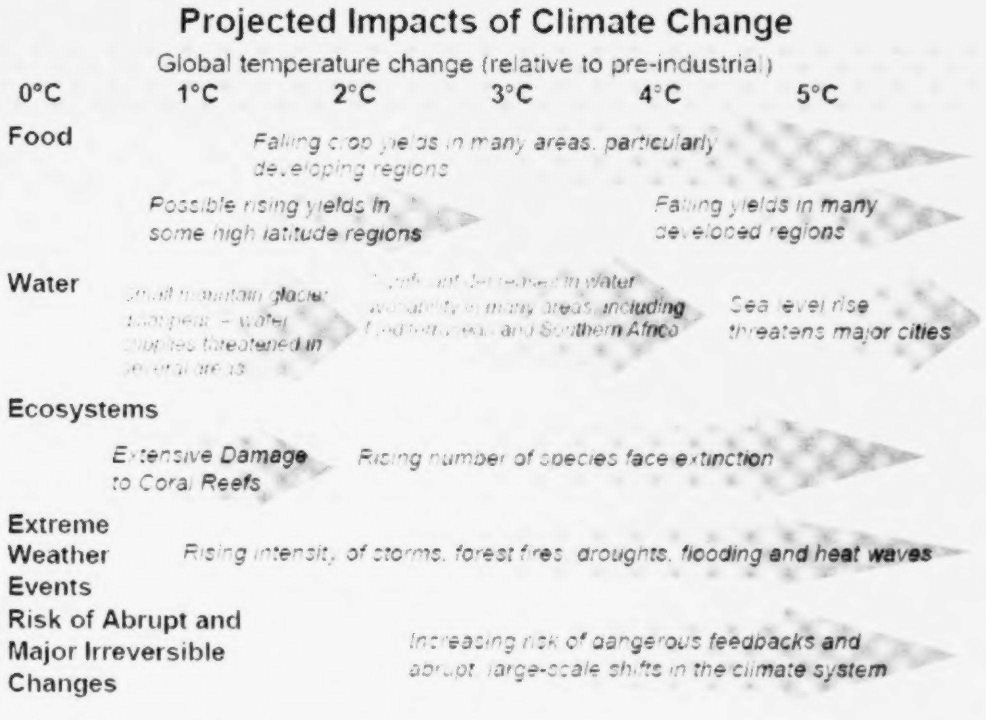
The global links between atmospheric temperatures, ocean circulation, sea level, and weather and storm patterns mean that changes to the climate from global warming will affect everyone. Because climate is the major factor controlling the global pattern of ecosystems, this is expected to result in changes to the ecosystems that people depend on for food, water, clean air, and economic activities. Also, built infrastructure (e.g., cities, ports, dams), agricultural systems, and other human activities will be affected because they have been based on past sea level and climate patterns. Figure 3 is from a recent British study (Stern 2006) showing the types of impacts that may be expected with each degree rise in average global temperature.

Some of the projected and observed changes include:

- **Physical impacts**, such as increasing frequency and severity of extreme weather (heat waves, drought, and high-intensity rainfall), changes in river flow, increased flood risk, increased wildfire risk, shrinking glaciers and snowpacks at most locations, rising sea level, and alteration of ocean temperature, salinity, and density.

- **Biological impacts** on ecosystems, such as changes to vegetation, species composition and distribution, ecosystem function (productivity, nutrient and water cycling), and distribution of ecosystems in the landscape. Timing of biological events, such as flowering, migration, growth, and reproduction, and interactions between species, will be affected. Patterns of natural disturbance (fires, pest infestations) and the impacts of alien species will also change.
- **Socio-economic effects**, including the economic cost of dealing with the impacts listed above. In particular, there will be costs due to extreme weather, flooding, and sea level rise, as well as costs of investing in conservation measures, developing alternative water supplies, building or replacing infrastructure, and possibly moving people to other locations. Ecosystem-based economic activities, such as agriculture, forestry, salmon fisheries, and tourism, will also be affected.
- **Health effects** will include increasing range of certain diseases (such as malaria) and increased risk of heat-related illnesses such as heat stroke.

Figure 3. Projected impacts of climate change with each degree increase in average global temperature.


Projected Impacts of Climate Change
Global temperature change (relative to pre-industrial)
0°C
1°C
2°C
3°C
4°C
5°C
Food
Falling crop yields in many areas, particularly developing regions
Possible rising yields in some high latitude regions
Falling yields in many developed regions
Water
Small mountain glaciers disappear – water supplies threatened in several areas
Significant decreases in water availability in many areas, including Mediterranean and Southern Africa
Sea level rise threatens major cities
Ecosystems
Extensive Damage to Coral Reefs
Rising number of species face extinction
Extreme Weather Events
Rising intensity of storms, forest fires, droughts, flooding and heat waves
Risk of Abrupt and Major Irreversible Changes
Increasing risk of dangerous feedbacks and abrupt, large-scale shifts in the climate system

Source: Stern Review on the Economics of Climate Change, 2006, reproduced with permission.

NATURAL SOURCES OF CLIMATE VARIATION IN BRITISH COLUMBIA

It is important to note that for B.C., the impacts on the climate from global climate change will interact, possibly unpredictably, with two major sources of natural short-term variation in the regional climate:

- The Pacific Decadal Oscillation (PDO) is a little-understood natural cycling of warm and cool phases in the sea surface temperatures of the Pacific Ocean. It appears to affect the B.C. climate over a 50- to 60-year cycle, spending roughly 20 to 30 years in each phase. In British Columbia, the warm phase of the PDO is generally associated with above-average air and ocean surface temperatures and below-average springtime snowpack. Some researchers feel that the cycle may now be beginning to shift toward a cool phase.
- The El Niño/Southern Oscillation (ENSO) phenomenon is related to shifts in tropical air pressure and ocean temperature that change temperature and precipitation patterns along the West Coast every few years. For British Columbia, an El Niño event generally means a warmer winter with below-average precipitation, and a La Niña event means a cooler winter with above-average precipitation.

The naturally large variability in air temperature, ocean temperature, and precipitation caused by these cycles and their interactions means that it takes a long series of observations to detect underlying long-term trends. Neither phenomenon is well understood and they may be changing as a result of changing climate in ways that may be both complex and unpredictable.

This paper presents indicators of climate change and trends in greenhouse gas emissions for British Columbia. It includes information on past trends as well as projected conditions for later in this century.

INDICATORS

1. Key Indicator: Long-term trends in air temperature in B.C.

This is a status indicator. It addresses the questions: Has the air temperature changed in British Columbia? What are the long-term trends in air temperature? How will it change in the future?

This indicator updates results reported in 2006 (BCMOE 2006) showing temperature trends in British Columbia taken from records over the past 50 years. Supplementary information follows that shows the projected increases in temperature by the middle of the century according to climate modelling.

Methodology and Data

This indicator uses Adjusted Historical Canadian Climate Data (AHCCD), available on the Environment Canada website (*www.cccma.bc.ec.gc.ca/hccd/*). Data were downloaded July, 2007. The AHCCD dataset has been adjusted to correct for non-climate related changes, such as a change in station location or instrument changes (Vincent and Gullet 1997; Mekis and Hogg 1999).

Records from 15 stations were used for the calculations shown in Table 1. Fourteen stations had continuous records from before 1950 extending through 2006, but Quesnel Airport records were to 2005 only. The stations represent three of the four climatic zones in British Columbia because updated data were not available for the North BC Mountains climatic zone.

Trends for the period 1950-2006 were calculated using the Microsoft Excel template MAKESENS (Salmi et al. 2002; available at *www.fmi.fi/organization/contacts_25.html*). The MAKESENS software uses the nonparametric Sen's linear estimate for the slope of the trend line and the nonparametric Mann-Kendall test to evaluate whether that slope is statistically different from zero (no trend). Before trend calculations, the data were checked for possible serial correlation using the Durbin-Watson statistic. The station data were adjusted for serial correlation (autocorrelation) using the prewhitening method of Wang and Swail (2001). This is a statistical procedure applied to climate data so that the subsequent analysis avoids overestimating the significance of a trend. Table 1 shows trends in the annually averaged daily minimum, mean, and maximum temperatures. Statistically significant increases are designated with asterisks.

Table 1. Trends in the average daily minimum (Tmin), mean (Tavg), and maximum (Tmax) temperatures per decade. Calculations are based on records from 1950 through 2006†.

			Change per decade (in °C)				
Station name	Climate Zone	Element	Annual	Winter	Spring	Summer	Autumn
Abbotsford Airport	Pacific	Tmin (°C)	0.40	0.88	0.48	0.32	0.13
		Tavg (°C)	0.33*	0.29*	0.38*	0.41*	0.15*
		Tmax (°C)	0.11	0.63	-0.23	0.67	-0.42
Comox Airport	Pacific	Tmin (°C)	0.32*	0.22*	0.44*	0.36*	0.21*
		Tavg (°C)	0.23*	0.22*	0.28*	0.25*	0.12*
		Tmax (°C)	0.13*	0.17*	0.13	0.15	0.06
Port Hardy Airport	Pacific	Tmin (°C)	0.21*	0.24*	0.28*	0.25*	0.02
		Tavg (°C)	0.19*	0.27*	0.20	0.17	0.04
		Tmax (°C)	0.15*	0.29*	0.23*	0.08	0.03
Victoria Airport	Pacific	Tmin (°C)	0.22*	0.20*	0.35*	0.25*	0.11*
		Tavg (°C)	0.25*	0.22*	0.32*	0.29*	0.12*
		Tmax (°C)	0.24*	0.29*	0.24*	0.27*	0.10
Fort St. John	Northwestern forest	Tmin (°C)	0.41*	1.06*	0.49*	0.18*	0.15
		Tavg (°C)	0.31*	0.98*	0.46*	0.11	0.05
		Tmax (°C)	0.35*	0.92*	0.43	0.05	0.00

Fort Nelson	Northwestern forest	Tmin (°C)	0.36*	0.83*	0.38*	0.12	0.15
		Tavg (°C)	0.36*	0.85*	0.48*	0.11	0.15
		Tmax (°C)	0.38*	0.82*	0.53*	0.10	0.10
Smithers	South BC mountains	Tmin (°C)	0.29*	0.65*	0.26*	0.17*	0.00
		Tavg (°C)	0.30*	0.56*	0.27*	0.14	0.02
		Tmax (°C)	0.25*	0.48*	0.29*	0.13	0.05
Burns Lake	South BC mountains	Tmin (°C)	0.16	0.55	0.21	0.14	-0.14
		Tavg (°C)	0.31*	0.60*	0.29*	0.19*	0.04
		Tmax (°C)	0.36*	0.62*	0.37*	0.29*	0.11
Quesnel Airport †	South BC mountains	Tmin (°C)	0.40*	0.80*	0.43*	0.17*	0.20
		Tavg (°C)	0.35*	0.64*	0.35*	0.17*	0.13
		Tmax (°C)	0.27*	0.44*	0.39*	0.13	0.03
Summerland	South BC mountains	Tmin (°C)	0.29*	0.33*	0.33*	0.36*	0.13
		Tavg (°C)	0.29*	0.29	0.32*	0.31*	0.14
		Tmax (°C)	0.27*	0.26	0.29*	0.27*	0.17
Cranbrook Airport	South BC mountains	Tmin (°C)	0.31*	0.42*	0.42*	0.28*	0.15
		Tavg (°C)	0.29*	0.32*	0.39*	0.23*	0.14
		Tmax (°C)	0.25*	0.27	0.39*	0.18	0.17
Kamloops Airport	South BC mountains	Tmin (°C)	0.43*	0.61*	0.39*	0.42*	0.21*
		Tavg (°C)	0.34*	0.52*	0.35*	0.24*	0.12
		Tmax (°C)	0.25*	0.44*	0.30*	0.06	0.04
Prince George Airport	South BC mountains	Tmin (°C)	0.40*	0.81*	0.47*	0.35*	0.10
		Tavg (°C)	0.38*	0.66*	0.43*	0.28*	0.11
		Tmax (°C)	0.35*	0.47*	0.44*	0.21	0.07
Revelstoke	South BC mountains	Tmin (°C)	0.33*	0.40*	0.38*	0.27*	0.17*
		Tavg (°C)	0.26*	0.43*	0.29*	0.13	0.13
		Tmax (°C)	0.18*	0.38*	0.23	0.00	0.10
Vernon	South BC mountains	Tmin (°C)	0.43*	0.56*	0.41*	0.34*	0.21*
		Tavg (°C)	0.37*	0.43*	0.40*	0.29*	0.18
		Tmax (°C)	0.29*	0.29	0.32*	0.25*	0.18

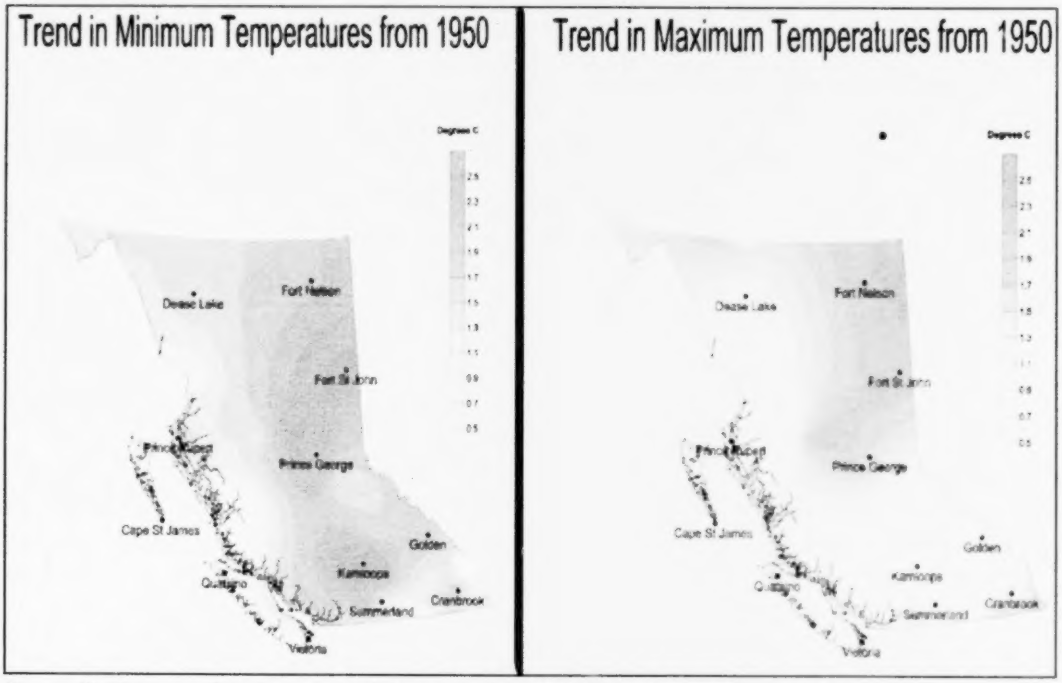
† Records for Quesnel Airport, 1950–2005.

Note: Asterisks indicate a statistically significant difference, meaning there is at least a 95% probability that the trend is not due to random chance.

Results show that there has been a statistically significant increase in the average temperatures (minimum, mean, and maximum) at most stations in the province. The addition of 5 new years to the data set (2002–2006) did not change the results much from trends reported previously for 1950-2001 (BCMOE 2006). Generally, the most recent calculations show slightly higher average increases per decade, reflecting the inclusion of five of the warmest years in the last 50 years. There was also an increase in the number of trends that were statistically significant, which increases confidence in the finding that British Columbia's climate has warmed significantly since the 1950s.

Figure 4 shows a graphical representation of temperature trends from 1950 to 2001, using records from 36 climate stations. For information on methods, data and locations of the stations used to calculate the trends shown in Figure 4, see the British Columbia Coastal Environment: 2006 report (BCMOE 2006).

Figure 4. Fifty-year trends in daily minimum and maximum temperatures shown as change (in °C), 1950–2001.


Trend in Minimum Temperatures from 1950
Degrees C
2.5
2.3
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
Dease Lake
Fort Nelson
Fort St John
Prince Rupert
Prince George
Cape St James
Golden
Kamloops
Quatsino
Summerland
Cranbrook
Victoria
Trend in Maximum Temperatures from 1950
Degrees C
2.5
2.3
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
Dease Lake
Fort Nelson
Fort St John
Prince Rupert
Prince George
Cape St James
Golden
Kamloops
Quatsino
Summerland
Cranbrook
Victoria

Source: Environment Canada: *www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm.*

Note: The graphic shows generalized temperature changes for the region but is not meant to represent accurate temperature changes for specific areas or locations.

Interpretation

British Columbia is experiencing a pattern of warming consistent with what has been observed globally. All stations showed increasing temperatures from 1950 to 2006, with the greatest changes occurring in the northern and interior regions (i.e., the Northwestern Forest climate zone). There were seasonal differences in trends per decade, with the least change occurring in the autumn over most of the province (the southwest is an exception).

The IPCC's Fourth Assessment reported that the average global warming trend over the last 50 years was 0.13 ± 0.03°C per decade, for a total increase of 0.65 ± 0.15°C for the 50-year period (Solomon et al. 2007). In British Columbia, both the average annual increase in mean temperature of 0.30 ± 0.04°C per decade and the total increase of 1.5°C during the last 50 years are higher than the global average. This is consistent with IPCC reporting, which shows that warming at higher latitudes has been greater than the global average (Solomon et al. 2007).

Within the province, the Northwestern Forest climatic zone had the largest increase in temperature, with winters warming faster than the other seasons. In the 1950 to 2006 period, the winter overnight low at Fort St. John increased by 5.3 ± 2.8°C, while the daily average winter temperature increased 4.9 ± 2.7°C. The South B.C. Mountains climatic zone also showed the greatest warming trend in the winter. The winter overnight low at Prince George has increased by 4.0 ± 3.0°C. The warming pattern in the Pacific climatic zone differed from the other regions, showing temperatures warming fastest in the spring. The springtime overnight low at Comox Airport increased 2.2 ± 1.5°C since 1950.

Overall, the overnight minimum air temperatures in the province have been increasing faster than the daytime maximums. This is creating a climate with a narrower daily temperature range and a longer growing season. Previous reporting also showed that there are also fewer days of frost each year (BCMOE 2006).

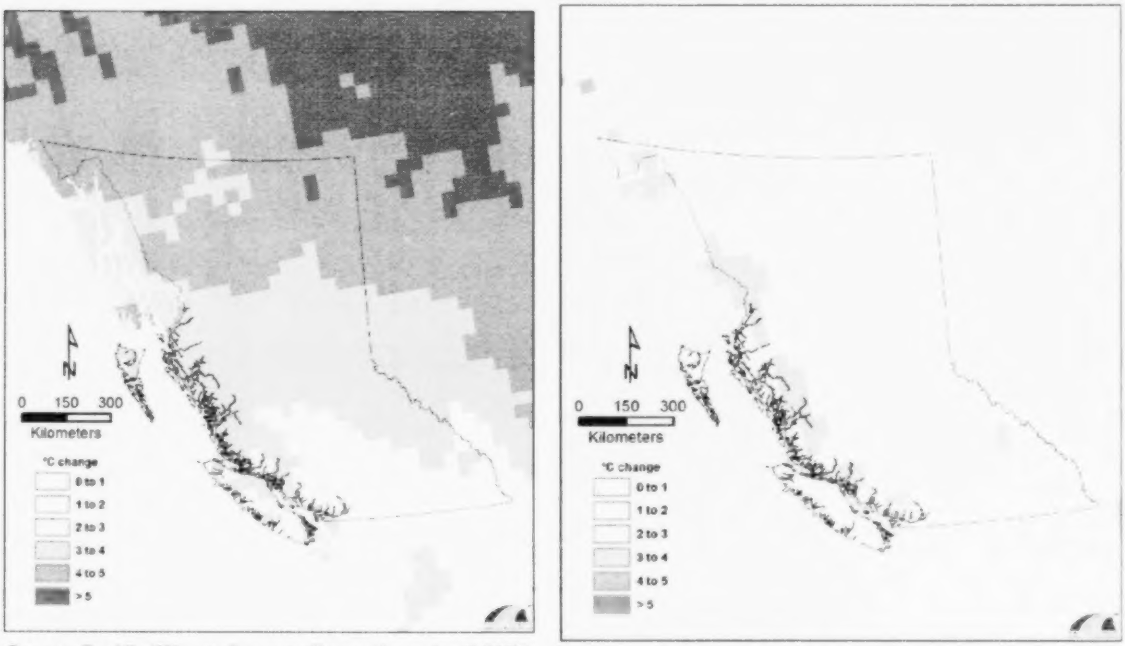
Supplementary Information: Temperature changes by mid-century in B.C.

The most recent IPCC assessment projects that globally averaged temperature will increase by at least 1.8 ± 0.7°C over this century (IPCC 2007a). Increases may be as high as 4.0 ± 2.4°C, depending on the extent to which society reduces the consumption of fossil fuels and controls greenhouse gas emissions by the end of the century. These projections were made using Global Circulation Models (GCMs), which have been developed and tested extensively since the 1980s. Such climate models balance calculations of incoming solar radiation against the outgoing planetary radiation and take into account the degree to which future greenhouse gas emissions will affect that balance. The models incorporate a series of specific emissions scenarios, which vary in their assumptions about future fossil fuel use and the actions that society may take to curb greenhouse gas emissions. The climate models are run using the range of greenhouse gas emissions under the different scenarios to produce a set of plausible outcomes.

Because global climate models operate on grids of 250 to 600 km across, they are not precise enough to characterize the smaller scale processes that influence temperature and precipitation at a provincial level. To develop regional projections for Canada, a team of researchers at the Consortium Ouranos developed the Canadian Regional Climate Model (CRCM) in collaboration with the Canadian Centre for Climate Modelling and Analysis. The CRCM runs on a 45-km grid and thus is designed to shows a finer, more regional scale of climate projection.

In April 2007, using the most recent version of this model (CRCM4.1.1) the Pacific Climate Impacts Consortium prepared projections of winter and summer temperatures for British Columbia. Figure 5 shows the projected temperature increases for a period in the middle of the 21st century (2041–2070) compared to the period 1961 to 1990, under the A2 emissions scenario. The model projects that winters will continue to warm faster than summers, reducing the contrast between seasons. Under this scenario much of the province would experience summers 2–3°C warmer by mid-century than occurred in the period 1961 to 1990. The northern half of the province would experience winters warmer by 3–5°C. These trends are projected to continue so that the province may be even warmer by the end of the century. Table 2 compares these climate model projections with regional average temperature increases accumulated in B.C. to date.

Figure 5. Temperature change projected for the middle of the 21st century (°C), compared to the 1961-1990 average. Left: Average winter conditions (December, January, February). Right: Average summer conditions (June, July, August).



Source: Pacific Climate Impacts Consortium, April 2007 (analysis). Consortium Ouranos and Canadian Centre for Climate Modelling and Analysis (data and modelling).

Notes: Initial boundary conditions for the Canadian Regional Climate Model that were used (CRCM4) were specified by output from the larger scale Canadian Global Climate Model CGCM3, using the IPCC SRES A2 emissions scenario. Resulting grids were mapped using ArcGIS software.

Table 2. Comparison of climate model projections with regional average temperature increases accumulated in B.C. to date.

Climatic zone	Season	Temperature increase 1976–2005	Model projection for increases to 2055 over 1976 baseline*
Pacific	Winter	0.7 °C warmer	2–4 °C warmer
	Summer	1.6 °C warmer	2–3 °C warmer
South BC Mountains	Winter	1.6 °C warmer	2–4 °C warmer
	Summer	0.7 °C warmer	2–3 °C warmer
Northwestern Forest	Winter	2.8 °C warmer	3–4 °C warmer
	Summer	No significant trend	2–3 °C warmer

* Output from CRCM4, A2 scenario.

One of most obvious consequences of rising temperature is that people in British Columbia can expect more hot days. There is a 90% chance that heat waves will increase in frequency (IPCC 2007a). Hot extremes will become more common as the climate warms and cold extremes will become less frequent. For the region that includes British Columbia, this means that by the end of the century, 14 to 19 new annual temperature records may be set every 20 years (Ravilious 2007). Extreme events, such as record high temperatures, are of critical importance because human health and the distribution of living organisms can be affected by extreme conditions more than by changes in average conditions.

2. Secondary Indicator: Coastal sea surface temperature

This is a impact indicator. It addresses the question: What is the impact of climate change on ocean temperature along the B.C. coast? This indicator was reported in the British Columbia Coastal Environment: 2006 report and is summarized here. For more detailed information see the full report (BCMOE 2006, *www.env.gov.bc.ca/soe/bcce/03_climate_change/ocean_temp.html*).

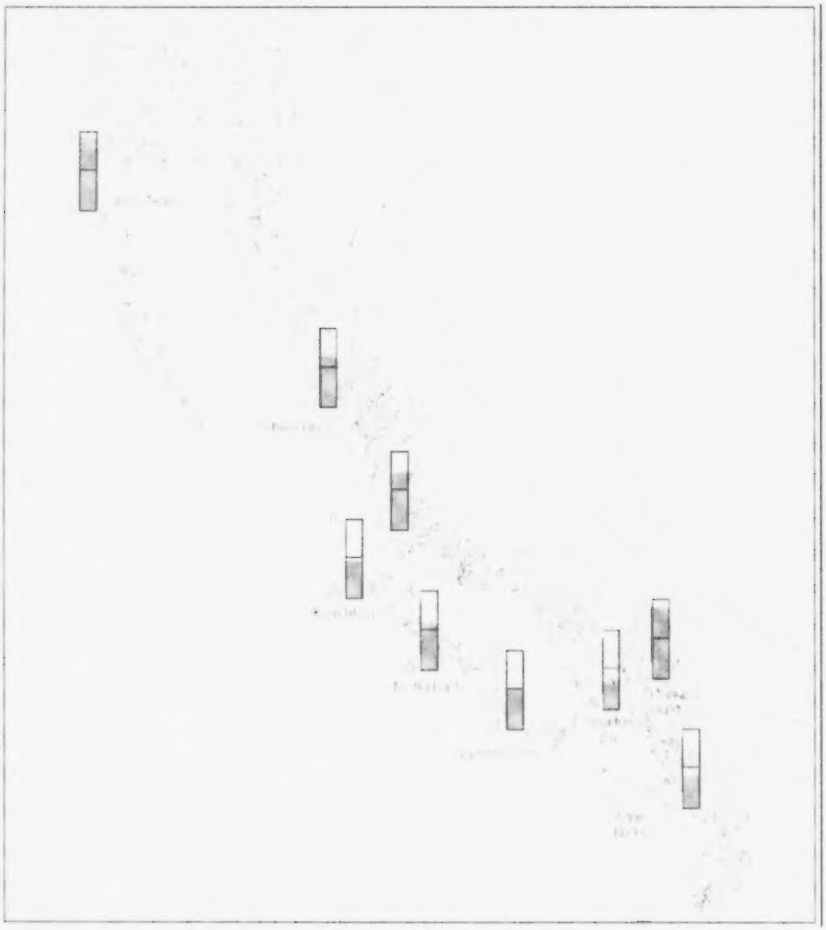
The temperature of the ocean affects coastal weather and climate. Along with salinity, ocean temperature affects the survival, growth, and reproductive success of marine life and the productivity and composition of marine ecosystems. The impacts of global climate change on the B.C. coast interacts with two major sources of natural variation in the ocean temperature: the Pacific Decadal Oscillation and the El Niño/Southern Oscillation phenomenon (see text box on natural sources of climate variation, above).

Methodology and Data

The longest water temperature series for the B.C. coast comes from daily surface observations taken at eight lighthouses and at the Pacific Biological Station in Departure Bay (Table 3) (available on Fisheries and Oceans Canada website *www-sci.pac.dfo-mpo.gc.ca/osap/data*). The annual mean temperatures reported here have been calculated from the monthly mean data for only those years where monthly mean values are available for all 12 months.

Trends were determined using the Microsoft Excel template MAKESENS and statistical analyses to remove any autocorrelation (using the pre-whitening procedure described in Wang and Swail 2001). Note that other methods for computing trends give slightly different results, both in terms of confidence intervals and the number of datasets showing significant positive trends. Regardless of the computational method, however, there is agreement in the overall finding that there are detectable and statistically significant increases in sea-surface temperature.

Figure 6. Rate of change in sea-surface temperature (°C/50 years) at nine lighthouse stations on the B.C. coast.



Source: Fisheries and Oceans Canada *www.pac.dfo-mpo.gc.ca/sci/osap/data.*

Note: Red bars indicate values that are statistically significant at <0.5%, meaning there is at least a 95% chance that the trend is real.

Table 3. Mean annual sea-surface temperature at nine stations on the B.C. coast.

Station	Area	First year	Latest year	Years used in analysis	Annual mean (°C)	Standard deviation (°C)	Trend (°C/50 yrs)
Langara Island	North coast	1941	2003	61	8.8	0.52	0.94*
McInnes Island	Central coast	1955	2003	46	9.6	0.48	0.65
Pine Island	Central coast	1937	2003	65	8.7	0.51	0.71*
Kains Island	West coast Vanc. Is.	1935	2003	68	10.2	0.55	0.43
Nootka Point	West coast Vanc. Is.	1935	2003	32	10.9	0.51	0.55
Amphitrite Point	West coast Vanc. Is.	1935	2003	68	10.4	0.52	0.50*
Departure Bay	East coast Vanc. Is.	1915	2003	68	11.1	0.50	0.29
Entrance Island	Strait of Georgia	1937	2002	65	11.2	0.51	0.82*
Race Rocks	Juan de Fuca Strait	1922	2003	64	9.1	0.44	0.39*

Source: Fisheries and Oceans Canada, *www-sci.pac.dfo-mpo.gc.ca/osap/data*.

Note: Asterisks indicate statistical significance. Probability or chance that there is no trend (α): <5%.

Interpretation

Over the last 50 years, the ocean has become warmer all along the B.C. coast (Figure 6). Five of the nine stations showed statistically significant increases in mean annual sea-surface temperature (Table 3). The largest and most significant increase was a warming of 0.9°C in 50 years for Langara Island, at the northwest tip of the Queen Charlotte Islands. The second largest change, 0.8°C in 50 years, was for Entrance Island, in the central Strait of Georgia.

A more detailed analysis reported in BCMOE (2006) showed three of the nine stations had statistically significant increases in either the annual maximum or annual minimum temperature. The most statistically significant trend was an increase in annual maximum temperature at Entrance Island. There was an increase of 1.7°C in 50 years at this station, which may reflect the increased summer warming in the Strait of Georgia.

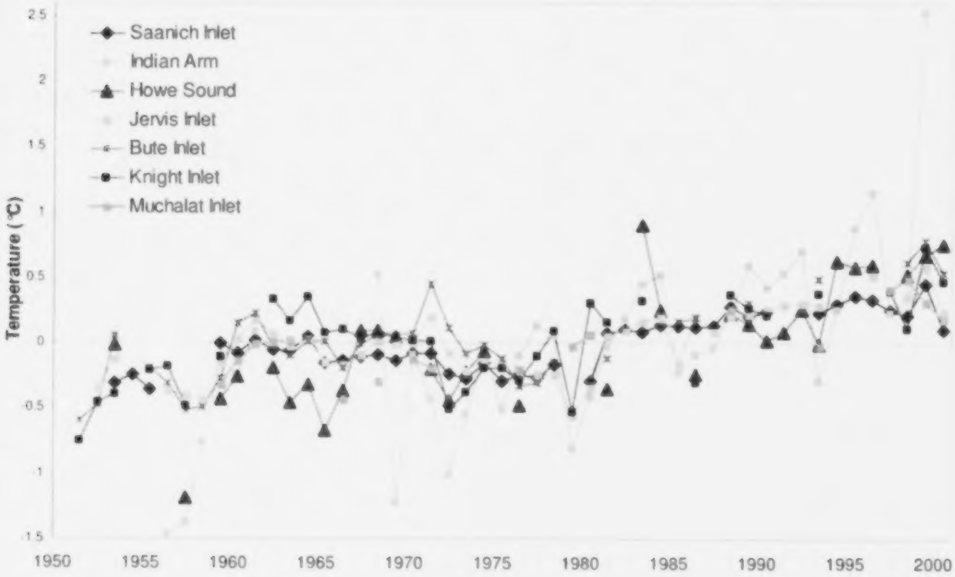
The water around Langara Island, at the extreme northwest point on the B.C. coast, is about 1.5°C colder than that around Amphitrite Point, on the southwest coast of Vancouver Island, for both annual mean and average annual extremes. At the present rate of increase, temperatures at Langara Island would resemble current conditions at Amphitrite Point in less than a hundred years.

Supplementary Information: Deep-water warming on the B.C. coast

A warming trend in the ocean along the southern B.C. coast also shows in the deeper waters of five inlets on the mainland coast and two on Vancouver Island. Consistent with the temperature trends shown in the sea-surface indicator, all seven inlets showed a warming of 0.5 to 1.0°C over the last 50 years.

Figure 7 shows temperature differences that depart from the average (set as 0°C) over the period for each time series. Bottom water temperatures in the inlets generally range from 6.5 to 8.5°C.

Figure 7. Deep-water temperature anomalies for inlets in southern B.C. The baseline of zero represents the average over the period for each time series.

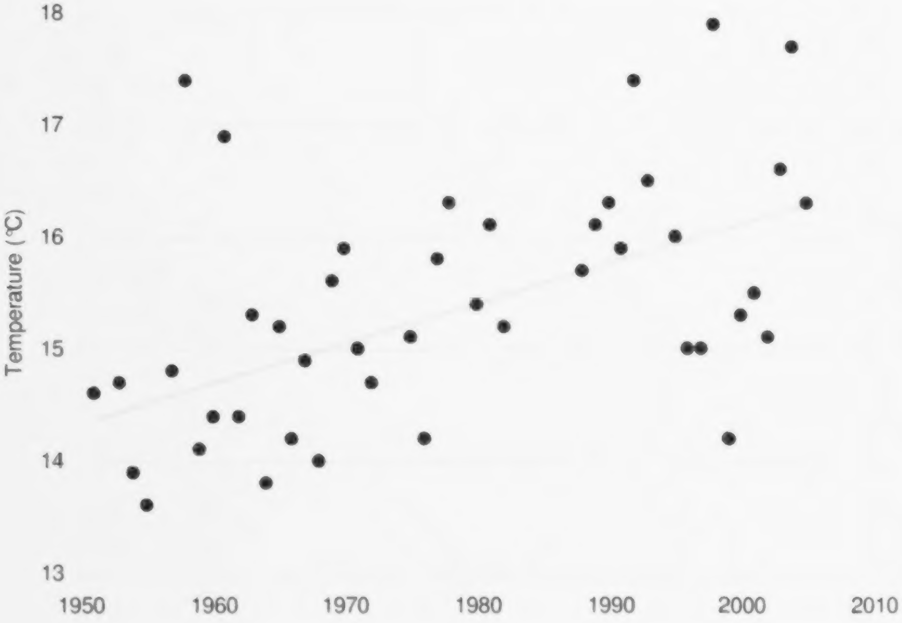


Source: Ocean Science and Productivity Group, Institute of Ocean Sciences, Fisheries and Oceans Canada, *www-sci.pac.dfo-mpo.gc.ca/osap/projects/bcinlets/intro_e.htm*.

Supplementary Information: Trends in stream and river temperatures in B.C.

Few long-term temperature datasets for rivers and streams are available, but the Pacific Salmon Commission and Fisheries and Oceans Canada have been measuring temperature in the lower Fraser River, at Hell's Gate. Interruptions in the data prevent an analysis for the years before 1950. Figure 8 shows that the average summer temperature in the river has been rising since 1950, at the rate of 0.3 ± 0.1°C per decade.

Figure 8. Average summer (June, July, August) temperature of the lower Fraser River at Hell's Gate.



Source: Pacific Salmon Commission and Institute of Ocean Sciences, Fisheries and Oceans Canada.

Water temperature increases with increasing air temperature and decreasing flow in the catchment basin above Hell's gate. Model projections suggest that the average water temperature at Hell's Gate will increase 1.5°C by the middle of the century and 1.9°C by the end of this century (Morrison et al. 2002). Projections also suggest that the average summer temperature in the Thompson River at Spences Bridge may reach 19.1°C by the end of the century.

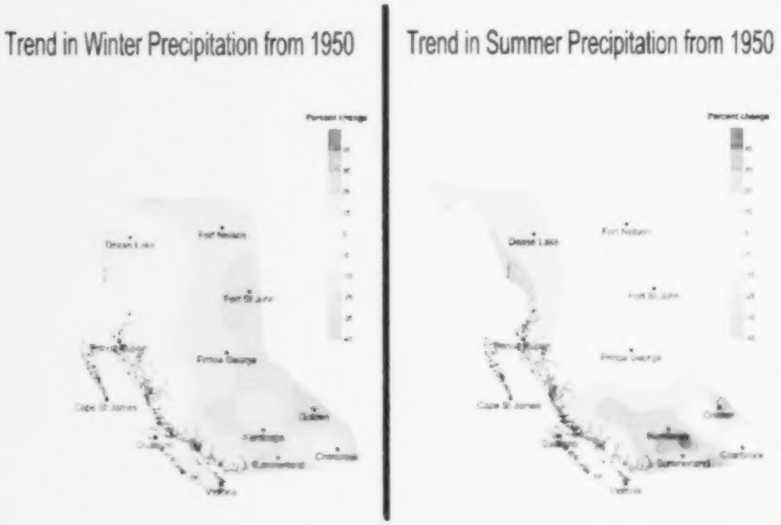
This is of vital importance to salmon, which are sensitive to high water temperature during their migration up-river to spawn. The Hell's Gate records show that before 1990, no daily temperature was above 20°C, but in 2004 there were 16 days above 20°C. Pre-spawn mortalities of sockeye of more than 90% have already occurred due to warmer water in some years (Lapointe et al. 2003; English et al. 2005). This raises concerns for the survival of many Fraser River salmon stocks later in this century as the temperature continues to rise.

3. Secondary Indicator: Precipitation changes in B.C.

This is a status indicator. It addresses the questions: How have precipitation patterns in British Columbia changed? How might climate change affect precipitation patterns in the future?

Precipitation (along with temperature) is one of the most important physical variables affecting terrestrial and coastal ecosystems. Trends in precipitation in the province over 50 years (1950–2001) were reported previously in BCMOE (2006) and are shown in an approximate graphical representation in Figure 9.

Figure 9. Fifty-year trends in winter and summer precipitation, shown as percentage change, 1950–2001.


Trend in Winter Precipitation from 1950
Trend in Summer Precipitation from 1950
Percent change
Dease Lake
Fort Nelson
Fort St John
Prince Rupert
Prince George
Cape St James
Golden
Kamloops
Quatsino
Summerland
Cranbrook
Victoria

Source: Environment Canada *www.ecoinfo.ec.gc.ca/env_ind/region/climate/climate_e.cfm*. For detailed information on methods, data and locations of the 36 stations used to calculate the trends shown see British Columbia Coastal Environment: 2006 (*www.gov.bc.ca\soe\bcce*).

Note: The graphic shows generalized precipitation changes for the region; it does not represent accurate changes for specific areas or locations.

The analysis showed that total annual precipitation (1950–2001) has increased in several regions of British Columbia. The Okanagan and North Coast regions show the largest increases. Eastern British Columbia has been receiving less precipitation on an annual basis. Winters throughout most of the province have been drier, whereas spring and summer seasons have been wetter.

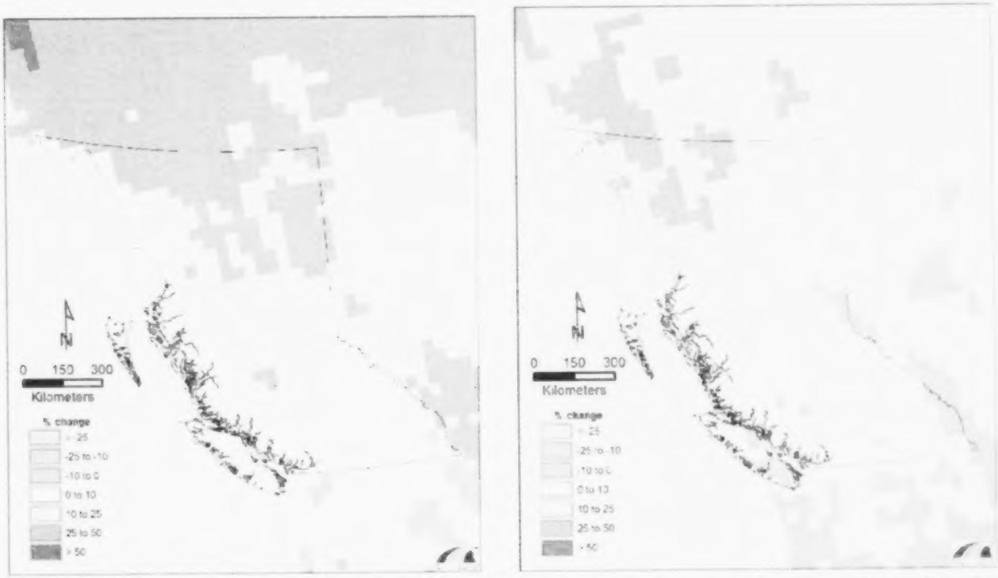
This indicator reports the results of the most recent climate modelling to project changes in precipitation for British Columbia by mid-century.

Methodology and Data

Methodology is the same as for the temperature projection described in Indicator 1. Figure 10 was produced by the Pacific Climate Impacts Consortium using data from the CRCM4.1.1 (the current Canadian Regional Climate Model developed by Consortium Ouranos and the Canadian Centre for Climate Modelling and Analysis) under the IPCC A2 emission scenario.

The two figures show precipitation differences between the middle of the 21st century (2041–2070) and the 1961–1990 period.

Figure 10: Projected change in precipitation by the middle of the 21st century, relative to historical records (1961–1990). Left: Average winter conditions (December, January, February); right: average summer conditions (June, July, August).



Source: Pacific Climate Impacts Consortium, April 2007 (analysis); Consortium Ouranos and Canadian Centre for Climate Modelling and Analysis (data and modelling).

Notes: Initial boundary conditions for the Canadian Regional Climate Model used (CRCM4) were specified by output from the larger scale Canadian Global Climate Model CGCM3, using the IPCC SRES A2 emissions scenario. Resulting grids were mapped using ArcGIS software.

Interpretation

Global climate models suggest that by mid-century there should be a small net increase in global precipitation and a redistribution of rainfall from the tropics into temperate and northern latitudes. A recent analysis of global observations from 1925 to 1999 showed that precipitation increased by 6.2 mm per decade in the latitude band of 50 to 70 degrees North, which includes almost all of British Columbia (Zhang et al. 2007). The analysis showed that human influence on atmospheric greenhouse gases could account for 50–85% of this observed trend.

Contrary to historical precipitation patterns, the model output shows precipitation may increase marginally over most of the province during winter, which is when much of the total rainfall for the year occurs. Summers, however, may become drier over much of the coast, especially in the south. On an annual basis (not shown in the figure), the entire province may become wetter. Less of the winter precipitation is likely to fall as snow, particularly at low elevations, because of the predicted rise in temperature.

There is some evidence that rainfall events are increasing in intensity (the amount of rain per unit time) and in magnitude. An analysis of precipitation data within Metro Vancouver (Greater Vancouver Regional District) found increases in rainfall intensity at about half the sites measured, especially for durations of less than 2 hours. In addition, high intensity events appear to be more frequent, especially in spring (Murdock et al. 2007). Modelling of mid-century precipitation using seven global climate models projects that the Vancouver area is more likely to experience drier summers and slightly wetter conditions in the other three seasons (Murdock et al. 2007).

4. Secondary Indicator: Changes in the spring snowpack in B.C.

This is an impact indicator. It addresses the question: Is the pattern of snowfall changing as a result of climate change?

This indicator presents the results of the analysis of trends in the accumulated snow water equivalent (SWE) in the snowpack over the last 50 years. SWE is the amount of liquid water contained in a volume of snow. Snow conditions in British Columbia vary widely from year to year as a result of natural variability in weather patterns due to the El Niño/Southern Oscillation (ENSO) effects and Pacific Decadal Oscillation (PDO) effects (see text box, above).

Methodology and Data

The B.C. Ministry of Environment operates a network of approximately 250 sites for manual and automatic sampling of snowpack. Some stations have been used since 1936 and many in the current sampling program have been in use since the 1950s, providing useful data on long-term trends in snow conditions. Sampling is done about April 1 each year, when there is a peak in the accumulated snowpack from the preceding winter.

For this indicator, April 1 SWE data for 73 long-term active manual snow courses were compiled from the River Forecast Centre snow archive website (*http://aardvark.gov.bc.ca/apps/mss/stationlist.do*) for the 50-year period, 1956–2005.

Monthly ENSO and PDO data were compiled from the National Oceanographic and Atmospheric Administration (NOAA) (*www.cpc.ncep.noaa.gov/data/indices*). An average ENSO and PDO variable for each April 1st snow survey was calculated as the numeric average of the monthly values from the preceding five months (November to March), corresponding to the winter snow accumulation period.

The data were analyzed with Systat v.11. First, a linear regression was fitted to each of the raw 50-year SWE data sets for each snow course. In general, the regressions were not statistically significant because there is such a large scatter from year-to-year. The trend from 1956 to 2005 was calculated from the regression slope and intercept coefficients.

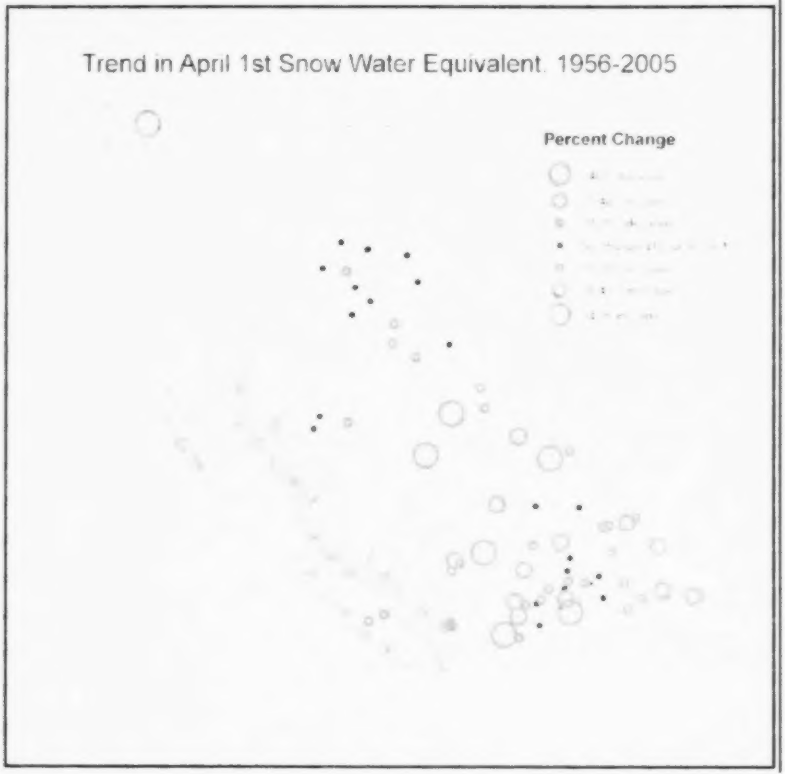
Overall, there were substantial downward trends in SWE from 1956 to 2005 (Figure 11 shows individual survey sites; Table 4 shows basin-wide averages). For the 73 long-term snow courses analyzed, SWE decreased on 63 courses and increased on ten. The largest decreases were in the mid-Fraser basin (Chilcotin Plateau, Bonaparte, Nicola, etc.; 47% reduction), Kettle (32%), Thompson (22%), Kootenay (23%), Upper Fraser (21%), and Columbia (20%) basins. The Peace, Skeena, Nechako basins had no notable change over the 50-year period. On average, across the province, the SWE was 18% lower in 2005 than in 1956.

Table 4. Average change in snow water equivalent for major river basins in B.C., 1956–2005.

Basin	Overall change (%)
Upper Fraser	–21
Nechako	–2
Middle Fraser	–47
Thompson	–22
Columbia	–20
Kootenay	–23
Kettle	–32
Okanagan	–14
Similkameen	–19
South Coast/ Vancouver Isl.	–17
Skagit	–39
Peace	–7
Skeena	+4
Yukon/Liard	+23

Source: River Forecast Centre, B.C. Ministry of Environment 2007.

Figure 11. Trend in April 1 snow water equivalent at long-term B.C. snow survey sites, 1956–2005.



Source: River Forecast Centre, B.C. Ministry of Environment 2007.

At the time of the 1976 PDO shift, there was a discontinuity in the raw SWE data and in the residuals of the regression analysis for many snow courses; the data were therefore also analyzed to test for relationships to the ENSO and PDO signal. The SWE data sets were regressed against the ENSO and PDO indices separately and in a multivariate model in an attempt to remove a signal in the snow data that may be related to ENSO and PDO. The residuals from the multivariate model were then examined for trends over the 1956 to 2005 period, on the assumption that trends in the snow data, with the ENSO and PDO effects removed, may indicate impacts of climate change.

The further analysis showed that variability associated with the ENSO and PDO signals may account for about one-half to two-thirds of the change over time. The PDO effect may be the dominant influence, because a substantial reduction in the snowpack occurred with the shift of the PDO from a cool phase to a warm phase in 1976. Although the average change in most basins was very small, there were some exceptions: the SWE for the mid-Fraser showed reductions of 27% over the 1956 to 2005 period, consistent with the general climatic trend.

which has been towards decreasing snow water, except in the north of the province. The Peace, Skeena, Liard, and Yukon basins all show increasing SWE.

Interpretation

Overall, the amount of water stored in snow and glaciers is expected to decrease globally as a result of climate change (IPCC 2007b). The results presented in this indicator may show such an effect in many of British Columbia's river basins, but this conclusion remains tentative. This is because the natural variability from other causes, such as the PDO and ENSO phenomena, is known to be large and complex and may also be shifting unpredictably due to climate change. Because these phenomena are not well understood, the statistical methods used to correct for these signals in the data may not be sufficient.

Declining snowpacks are a concern because they affect many aspects of water resources, from instream flows for fish to community water supply, soil moisture, groundwater, and aquifer recharge. Reinforced by the warm phase of the PDO, the raw B.C. snow survey data show declines of up to 73% in the Fraser Basin since 1951. Springtime snowpack has declined 20–40% in the Columbia River Basin (Sandford et al. 2006). It is not yet clear whether the warm phase of the PDO may be coming to an end, nor how much the loss in snowpack might recover when the PDO shifts to its next cool phase.

Supplementary Information: Increasing glacial melt and earlier stream flow

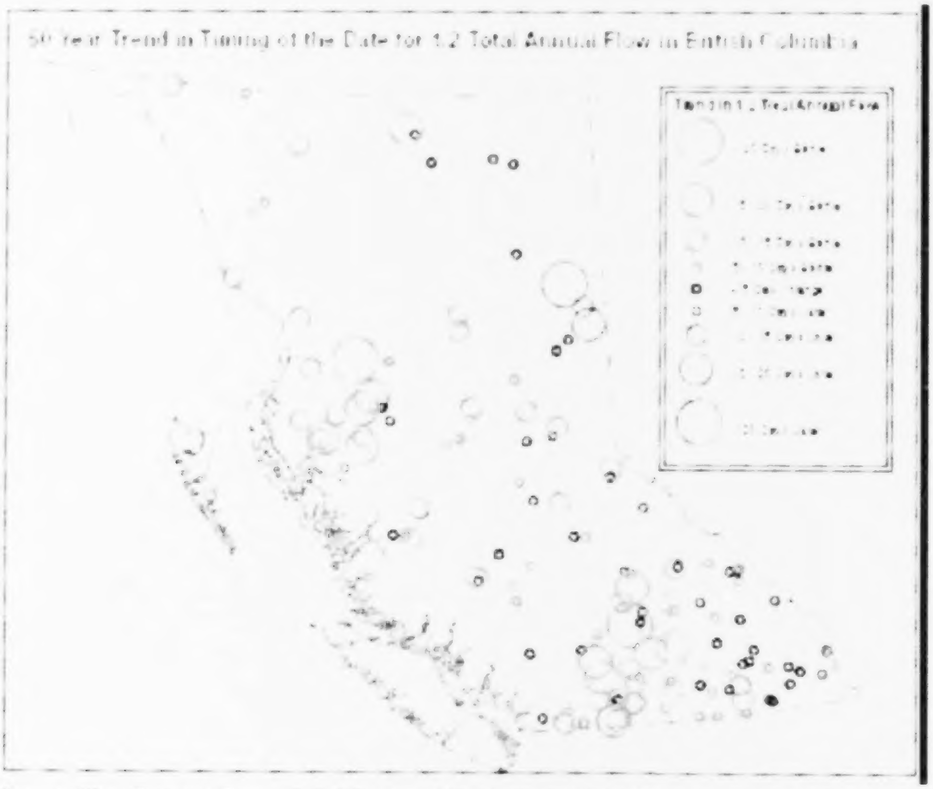
Mountain glaciers in temperate zones are highly sensitive to changes in the climate. Maritime glaciers, such as the Place, Helm, and Sentinel glaciers in the Coast Mountains, are highly sensitive to variations in winter precipitation, whereas glaciers in the Rockies, such as the Peyto glacier in Banff National Park, are more sensitive to summer temperatures (Lewis and Smith 2004).

Streams and rivers in much of B.C. are fed by melting ice and snow from the winter accumulation of snow (snowpacks) and from glaciers. In northwestern B.C., glacier-fed streams have become larger, whereas snowmelt-fed streams have become smaller over the period 1953–1999 (Fleming and Clarke 2003). Increasing glacial melt has probably had a greater effect on streamflow than changes in precipitation (Fleming and Clarke 2003).

Warmer winter and spring-time temperatures, especially at elevations below 1200 metres, have caused rivers to swell earlier in the year. Figure 12 shows the 50-year trend calculated for 140 stream-gauging stations where the annual discharge of water mainly comes from snowmelt. Stations in the southwest of the province were not included because the stream discharge there comes mainly from winter rain events rather than snowmelt.

The largest changes in river flow have been in the Okanagan-Kootenays and the north coast region of the province. Several stations show that the half-flow date (when half of all water in the river for the year has been discharged) now occurs more than 15 days earlier. The northeast mountains region is the exception, where three stations show a later half-flow date.

Figure 12. Fifty-year trend in timing of the date for half the total annual stream discharge in B.C., 1956–2005.


50 Year Trend in Timing of the Date for 1/2 Total Annual Flow in British Columbia

Source: River Forecast Centre, B.C. Ministry of Environment, July 2007.

B.C.'S RETREATING GLACIERS

The effect of changing temperature and precipitation on glaciers is extremely complex because it depends on the size, elevation, and location of the glacier, variations in the ENSO/PDO signal, as well as on climate change. For example, glaciers on the south coast have lost considerable mass since 1976 when the Pacific Decadal Oscillation (PDO) entered a phase with dryer winters and higher temperatures (Lewis and Smith 2004).

As observed in other parts of the world, many glaciers in B.C. are shrinking:

- Garibaldi Provincial Park: Despite brief periods of advancing, overall the glaciers in the park retreated through most of the 1900s. The area of ice in the park has decreased by about 240 km^2 (38%) since the late 17th or early 18th centuries (at the end of the cool climate period known as the Little Ice Age). Some glaciers in the park may vanish completely this century if present trends continue (Koch 2006).
- Strathcona Provincial Park: Moving Glacier has retreated almost a kilometre from its maximum extent in the early 1800s and had lost 90% of its surface area by 1992 (Smith and Laroque 1996).
- Mt. Waddington area of the central coast: The Tiedemann Glacier has retreated 2.1 km over the last century (Laroque and Smith 2005).
- Columbia River Basin: In the 15 years up to 2000, glaciers in the Columbia Basin lost an average of 16% of their area, with the Slocan watershed losing 47% and the Bull watershed losing 60% of total glacier area. These recession rates are consistent with rates being observed worldwide (Sandford et al. 2006).

5. Key Indicator: Mean sea level

This is a status indicator. It addresses the questions: Is sea level rising along the B.C. coast? This indicator was reported in greater detail in the British Columbia Coastal Environment: 2006 report (BCMOE 2006) and is summarized here (see *www.env.gov.bc.ca/soe/bcce/03_climate_change/sea_level.html*).

The average rate of sea level rise is increasing globally due to the acceleration of global warming. Observed global sea level rise in the period 1993–2003 was 3.1 mm per year, which is 72% higher than the observed average for the period 1961–2003 (IPCC 2007a). About half of the recent rise is estimated to be due to the expansion in volume of seawater as it warms; most of the rest is due to the increased flow of freshwater from melting glaciers on land (mainly Greenland) (IPCC 2007a).

Sea level rise is not uniform over the globe. It varies from one ocean basin to the next, reflecting variations in ocean heating and the effect of ocean currents and circulation. Along the B.C. coast, this includes large-scale variation in ocean circulation from the ENSO phenomena. Sea level along the B.C. coast is also affected by the geological movement of Earth's crust.

Rising sea level may be expected to result in more frequent flooding and salt contamination of low-lying areas. In combination with extreme weather, high tides and storm surges may be expected to damage areas and structures previously above high water.

Methodology and Data

Water levels along the British Columbia coast are recorded by tide gauges at stations maintained by the Canadian Hydrographic Service and the Water Survey of Canada. This indicator reports data from four tide gauge stations with long records that broadly represent three coastal oceanic regions (Table 5).

Table 5. Annual change in mean sea level since first year of records at four locations on the B.C. coast.

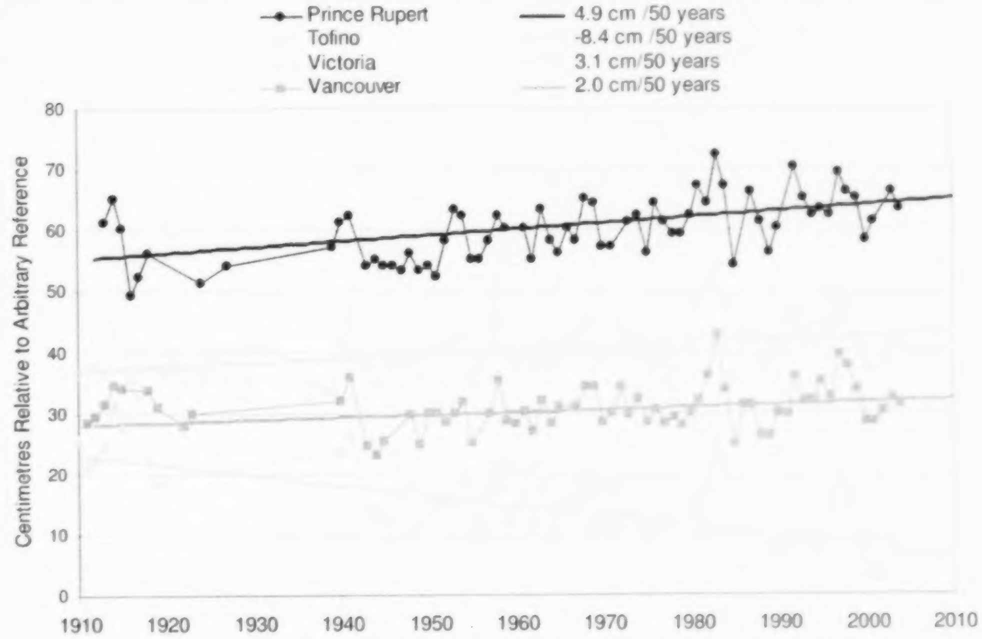
Station	First full year	Latest full year	Years used	Annual mean (cm)	Standard deviation (cm)	Trend (cm/50 years)	Chance of no trend
Prince Rupert	1913	2004	68	384.7	4.9	4.9	<0.05
Tofino	1910	2004	60	213.5	6.3	–8.4	<0.001
Vancouver	1911	2004	69	305.7	4.8	2.0	>0.1
Victoria	1910	2003	90	187.4	4.0	3.1	<0.01

Source: Marine Environmental Data Service, Fisheries and Oceans Canada.

Sea level data were obtained from the Marine Environmental Data Service (MEDS) of Fisheries and Oceans Canada. Trends were fitted to annual mean values to assess mean sea level rise. Trends were determined using the Microsoft Excel template MAKESENS, and statistical analyses to remove any autocorrelation (using the prewhitening procedure described in Wang and Swail 2001).

For Figure 13, the data were rescaled by adding a unique elevation to all the data for each station so that it could be displayed without overlapping on the same graph.

Figure 13. Changes in annual mean sea level at four locations on the B.C. coast.



Source: Marine Environmental Data Service, Fisheries and Oceans Canada.

Note: Trend lines were fitted using MAKESENS.

Interpretation

The analysis of sea level records shows that relative sea levels have been rising at Prince Rupert, Vancouver, and Victoria, but falling at Tofino. Differences between stations are explained on the basis of geological processes, which cause vertical movements of the shoreline that partly or completely cancel the effects of global sea level rise. The landmass of British Columbia is rebounding vertically (isostatic rebound) after the massive ice sheet melted approximately 10,000 years ago. The rate of rebound along the coast is estimated to be 0 to 4 mm per year. Also, the western edge of the North American continent is sliding over adjacent oceanic plates, resulting in crustal uplift estimated to be as high as 4 mm per year along the southwest coast of Vancouver Island near Tofino (Peltier 1996). The effect is that the measured water level drops as the coast (and the zero datum point) rises.

The magnitude of these effects means that short-term natural variations in mean sea level can be greater than the cumulative rise over the entire period. From 1980 to 1983, mean sea level rose by 12 cm in Victoria and Vancouver and by 10 cm in Prince Rupert. However, from 1983 to 1985 it declined by 19 cm in Victoria, 17 cm in Vancouver, and 18 cm in Prince Rupert. Both of these changes were associated with an ENSO event. Nevertheless, at all stations except Tofino, continuing the long-term trend in sea level would result in relative sea levels higher than have yet been observed.

Total global sea level rise in the 20th century was 170 mm, and the recent rate of global sea level rise was 2.3–3.9 mm/yr for the years 1993–2005 (Bindoff et al. 2007). The IPCC's projection for sea level rise this century is 18–59 cm, with a further 20 cm possible if the rate of ice loss in Greenland and Antarctica increases (IPCC 2007a). A more recent re-analysis of historical data suggests that the IPCC estimates are conservative and that sea level might rise by as much as 0.5–1.4 m during this century (Rahmstorf 2007).

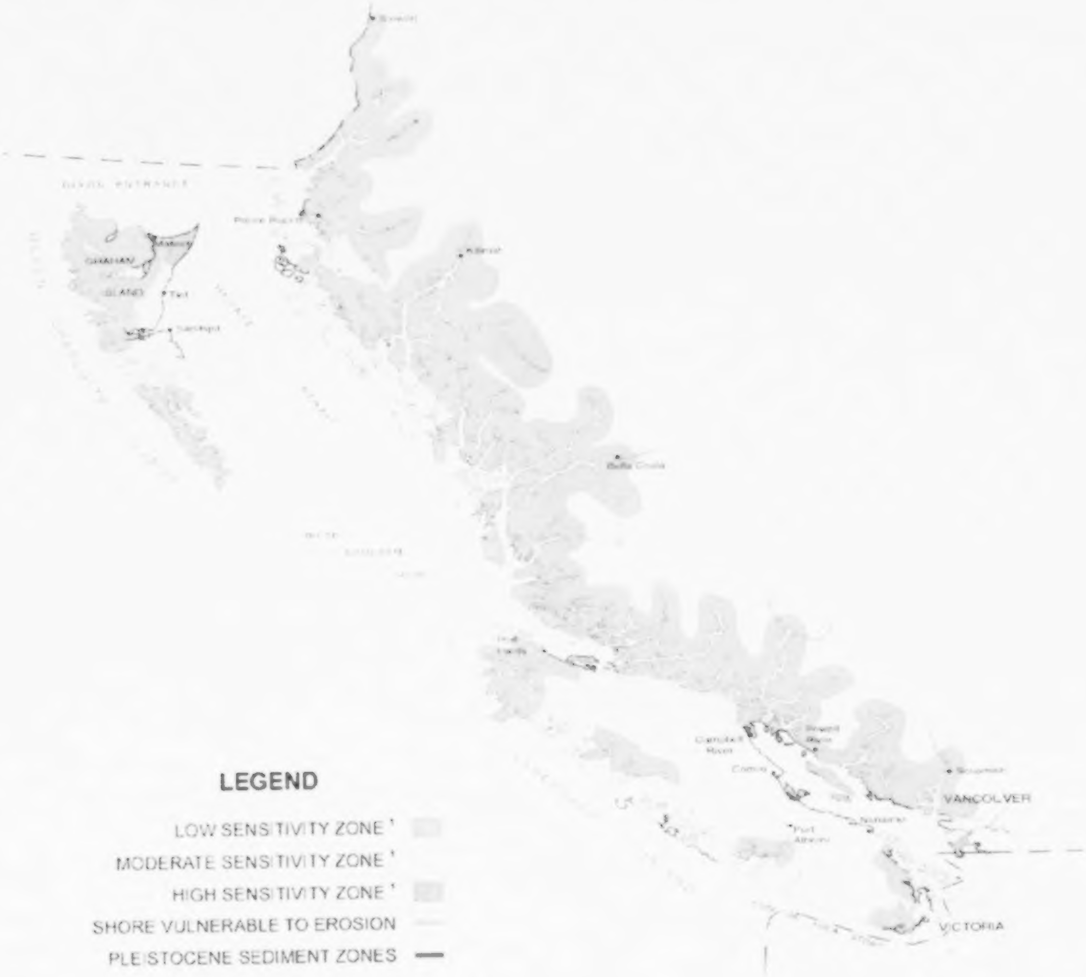
SEA LEVEL RISES AS GREENLAND'S ICE MELTS

As much as 0.6 mm/yr of the annual average sea level rise globally has been attributed to the melting of Greenland's ice (Mitrovica et al. 2001). The bulk of Greenland's ice, more than 3,000 metres above sea level in the centre, is a remnant from the last ice age. Because the centre is so high and the average air temperature over it is so cold, the centre of Greenland is still accumulating snow (Lemke et al. 2007). However, Greenland's ice cap flows naturally from the centre of the island to the edges. The mass of new snow in the interior has been roughly balanced by the loss of ice at the margin (Scheirmeir 2004), but the rate of loss is accelerating (Rignot and Kanagaratnam 2006). Models suggest the ice sheet may become permanently unstable if the average global temperature increases by 1.9–4.6°C relative to 1960. The lower end of this range could be reached within 50 years (IPCC 2007a).

Supplementary Information: Sensitivity of the B.C. coast to rising sea level

The projected rise in sea level due to climate change is a practical concern on the B.C. coast. Sections of the B.C. coast that are particularly sensitive to rising sea levels are the Fraser Delta region, which is subject to subsidence, and the Naikoon area of the Queen Charlotte Islands, which is presently eroding (Figure 14). In these areas, changing weather patterns coupled with sea level rise increase the risk of erosion and flooding under extreme weather conditions. The parts of the coastline with rocky, relatively steep-sided fiords are not considered sensitive to rising water.

Figure 14. Sensitivity of the B.C. coastline to sea level rise and erosion.


DIXON ENTRANCE
GRAHAM ISLAND
Prince Rupert
Bella Coola
Campbell River
Comox
VANCOUVER
VICTORIA
LEGEND
LOW SENSITIVITY ZONE ^{1}
MODERATE SENSITIVITY ZONE ^{1}
HIGH SENSITIVITY ZONE ^{1}
SHORE VULNERABLE TO EROSION
PLEISTOCENE SEDIMENT ZONES

Source: Hay & Co. Consultants 2004.

6. Key Indicator: Trends in greenhouse gas emissions in B.C.

The quantity of greenhouse gases emitted to the atmosphere is a pressure indicator. It is an indicator of human activity that is affecting the global atmosphere and is causing most of the increase in global temperatures. Greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and other trace compounds as well as water vapour.

Globally, the level of atmospheric CO_2 has increased by about 95 ppm since 1780. Of this increase, 84% is estimated to be due to emissions from fossil fuel combustion. The rest of the rise may be due to the alterations in land use, such as reduction in the global CO_2 sink due to forestry and forest fires (Kharecha and Hansen 2007). Carbon dioxide emissions account for more than 78% of the greenhouse gas emission in Canada and 79% of the emissions from facilities in B.C. (Environment Canada 2004).

This indicator examines the trends in total greenhouse gas emissions in British Columbia, as well as per capita emissions. It also shows how the province compares with other jurisdictions in North America.

Methodology and Data

Data on greenhouse gas emissions are from Environment Canada (2007) National Inventory Report, 1990-2005 - Greenhouse Gas Sources and Sinks in Canada: *www.ec.gc.ca/pdb/ghg/ghg_home_e.cfm*. The data were collected by Environment Canada and reported internationally using methods set out by the UN Framework Convention on Climate Change. The data were gathered by sector and subsector for industrial, commercial, and institutional sources, as well as for other sources such as transportation, agriculture, and land use change. Per capita greenhouse gas emissions shown in Table 6 and Figure 15 were calculated using population data from Statistics Canada's CANSIM database (*http://cansim2.statcan.ca*) using Table 051-0001, estimates of population, by age group and sex for July 1, Canada, provinces and territories, annual (persons), 1971 to 2007.

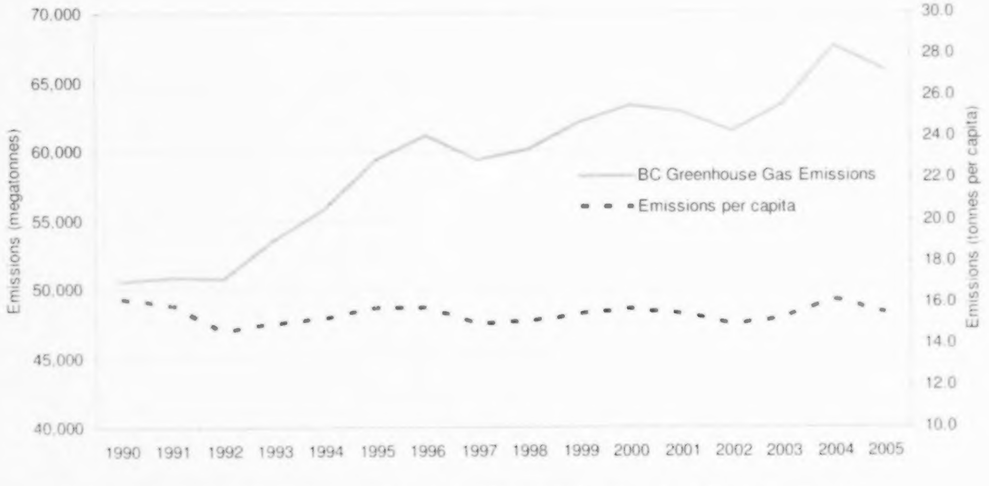
Emissions from specific industries were generated using the online inquiry function of Environment Canada's greenhouse gas emissions database: *www.ec.gc.ca/pdb/ghg/onlinedata/dataSearch_e.cfm*.

Table 6. Total and per capita greenhouse gas emissions in B.C., 1990–2005.

Year	B.C. population x 1,000	Total greenhouse gas emissions (tonnes)	Per capita greenhouse gas emissions (tonnes)
1990	3132.5	50,600	16.2
1991	3212.1	50,837	15.8
1992	3476.9	50,756	14.6
1993	3574.6	53,540	15.0
1994	3670.8	55,806	15.2
1995	3762.9	59,300	15.8
1996	3882.0	61,100	15.7
1997	3959.7	59,300	15.0
1998	3997.5	60,100	15.0
1999	4028.1	62,100	15.4
2000	4039.2	63,300	15.7
2001	4078.4	62,800	15.4
2002	4115.4	61,400	14.9
2003	4154.6	63,400	15.3
2004	4201.9	67,600	16.1
2005	4257.8	65,900	15.5

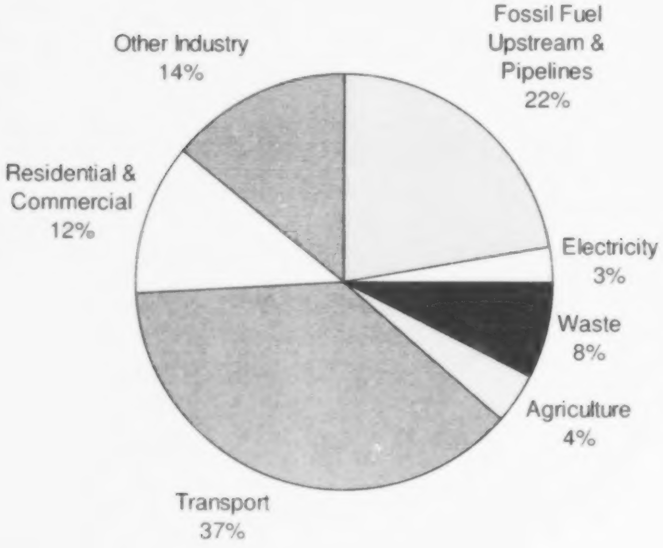
Source: Emissions data from Environment Canada (2007); population data from Statistics Canada.

Figure 15. Trends in total and per capita greenhouse gas emissions in B.C., 1990–2005.



Source: Emissions data from Environment Canada 2007; population data from Statistics Canada.

Figure 16. Greenhouse gas emissions in B.C. by sector, 2005.



Source: Environment Canada 2007.

Interpretation

Total greenhouse gas emissions for British Columbia rose 29.7% between 1990 and the end of 2004 (Figure 15, Table 6). This increase is slightly higher than the Canadian national average of 27%. The increase in emissions closely matched the provincial population growth of 28% over that period. There was a slight decrease in total emissions for B.C. in 2005, but it is too soon to tell whether this is the beginning of a longer trend.

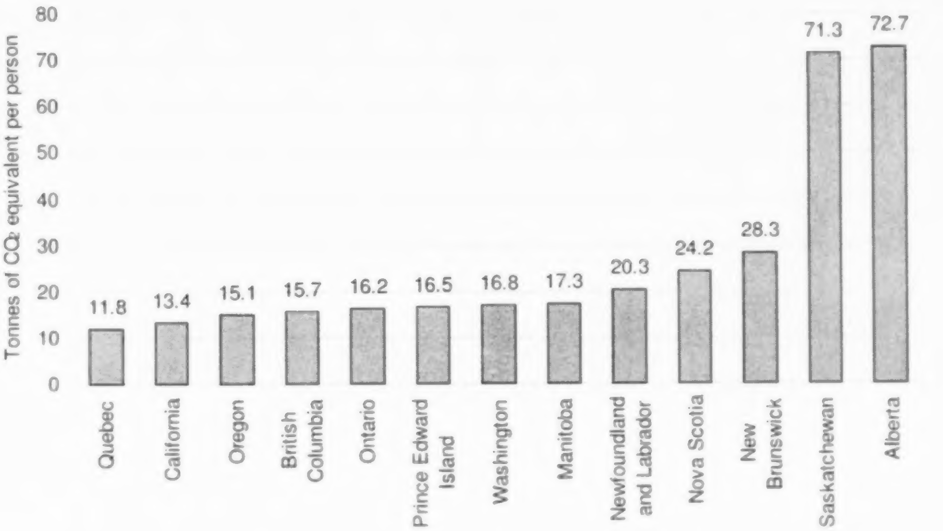
Of the various sectors, transportation has consistently been the largest source of greenhouse emissions (Figure 16). In B.C., transportation emissions have grown 42% since 1990, considerably faster than the national average of 30%. The transportation sector in B.C. produces a relatively larger fraction of total emissions (37% of the provincial total) than the national average (24%). This is because electricity generation and the home heating sector are relatively less important sources of greenhouse gases in B.C. Electricity generation for Canada is the source of 17% of emissions, whereas in B.C., which relies mainly on hydroelectric power, it accounts for only 3% of emissions.

Greenhouse gas emissions from industry, including the production of oil and gas, amount to 36% of B.C.'s total. In 2005, emissions from B.C.'s 10 largest industrial sources (e.g., natural gas plants, cement plants, aluminium smelter) accounted for almost 15% of B.C. total emissions.

Supplementary Information: How does B.C. compare with other jurisdictions in North America?

Greenhouse gas emissions per capita in B.C. are the second lowest in Canada (Figure 17). Emissions per capita are much lower in B.C. than in Alberta and Saskatchewan, largely due to B.C.'s abundant hydroelectricity. In Alberta, electricity generation and the production and refining of fossil fuels generate 72% of that province's emissions (Alberta 2005); about 50% of Alberta's electricity production comes from coal-fired generating plants. Saskatchewan's energy production industry, combined with a relatively low population, account for that province's high per-capita emissions.

Figure 17. Per capita greenhouse gas emissions for jurisdictions in Canada and the west coast US states.



Source: Canadian emissions data from Environment Canada 2007; 2004 population estimates from Statistics Canada; US data compiled by the Climate Change Section, B.C. Ministry of Environment.

Supplementary Information: Conventional and alternative energy sources in Canada

More than 80% of Canada's greenhouse gas emissions comes from the combustion of various types of fossil fuel. About half of the fuel emissions come from combustion of oil and petroleum products, and most of the rest comes from natural gas and propane (Environment Canada 2007).

Although the production and consumption of energy in Canada continues to rise, the use of oil, petroleum products, and natural gas cannot continue to expand indefinitely. Canada's production of natural gas, for example, reached a peak in 2005, and Natural Resources Canada projections show natural gas usage is likely to decline, especially after 2015 (NRCan 2006). Production of conventional oil in Canada is also expected to decline, with Alberta's oil sands becoming the main source of oil by 2020 (NRCan 2006).

Energy analysts do not agree on how long the recoverable supply of oil and gas can support the current demand (USGAO 2007). Regardless of whether more conservative or more growth-oriented predictions are borne out, analysts question whether the global atmosphere can safely accommodate the carbon emissions associated with burning the recoverable reserves (e.g., Foucher 2007; Witze 2007). Replacing a unit of oil-fired electricity with a unit of coal-fired electricity without sequestering the carbon will increase CO_2 emissions by 24% (Environment Canada 2006b). Carbon sequestration technology would capture CO_2 and dispose of it in long-term storage in the ground, but currently (2007), no coal-fired generation plants with a carbon capture and storage facility were in operation at full-scale (Chipman 2007).

Part of the solution is replacing conventional oil with fuels derived from plants and organic waste. Biomass combustion is considered to be carbon neutral because the CO_2 emitted on combustion was previously removed from the atmosphere as the biomass grew. Currently, B.C. leads Canada in the use of biomass for energy. The province has 50% of Canada's biomass electricity generating capacity. In 2005, the B.C. forest industry generated the equivalent of $150 million in electricity and roughly $1.5 billion worth of heat energy. The use of biomass has also displaced some natural gas consumption in the pulp and paper sector (BCMEMPR 2007).

Ethanol is another plant-based fuel made from starch, sugar, or cellulose from corn or other crops. It already replaces a portion of fossil fuels in motor gasoline. The B.C. Energy Plan will implement a 5% average renewable fuel standard for diesel by 2010 and will further support the federal action of increasing the ethanol content of gasoline to 5% by 2010. However, agricultural production limits the degree to which ethanol made from corn can be substituted into gasoline, and there are concerns that fuel with a high ethanol content may increase the smog from vehicles (Jacobson 2007). Pure ethanol has less energy content per litre than gasoline, therefore a car fuelled with a 10% ethanol blend burns more fuel to travel the same distance as a car running on pure gasoline. As a result, the net greenhouse gas emissions using ethanol blends are only 3–4% lower (NRCan 2007b).

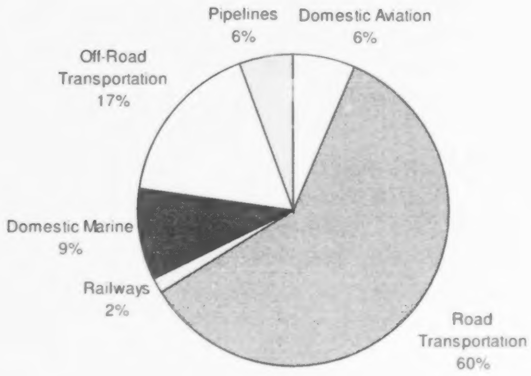
Methane gas captured from decomposing waste is being used to power electrical generators at a growing number of B.C.'s landfills. Power generation from renewable resources is increasing rapidly. Canada's installed wind energy generation capacity doubled in 2006, to 1,341 Mw (CWEA 2006). Although currently none of that installed capacity is in British Columbia, B.C.'s first wind plant is scheduled to bring 25 Mw of capacity online in 2007 (CWEA 2007).

7. Secondary Indicator: Trends in fossil fuel use in the transportation sector in B.C.

This is a pressure indicator, showing the trends in automobile types and use patterns in the province.

In B.C., the transportation sector is responsible for more than a third of all greenhouse gas emissions (Figure 16). Most (60%) of the emissions from the transportation sector come from road vehicles (Figure 18), and most of the road vehicle emissions (65% in 2005) comes from the light passenger vehicles (motorcycles, cars, pickups, minivans, and SUVs). Heavy diesels, such as transport trucks and buses, were the source of most of the rest of road transportation emissions (30%; data from Environment Canada 2006a).

Figure 18. Greenhouse gas emissions from the transportation sector in B.C. in 2005.



Source: Environment Canada 2007.

Emissions of CO_2 from road transport are directly related to how much fuel vehicles consume per kilometre and how far they are driven. This means that the type of vehicle people choose to buy has an important impact on greenhouse gas emissions. For example, when driven for 25,000 km, an average light truck or SUV produces about 2 tonnes more greenhouse gases than an average car. Based on data from Natural Resources Canada's Fuel Consumption Guide (NRCan 2007a), a new gasoline-electric hybrid car would produce about one-third the emissions of a new mid-sized SUV.

Methodology and Data

Data for this indicator were current up to the date obtained (January 2007) from Statistics Canada's CANSIM database (Statistics Canada 2007).

New vehicle sales data came from CANSIM Table 079-0001 (Figure 19). The figure shows sales in two classes of vehicles:

- Cars: regular passenger cars only, and
- Other: light trucks, heavy trucks and vans, buses and coaches. Sales of new pickups, minivans, SUVs and crossover vehicles, make up by far the largest proportion of the Other category (see Figure 19).

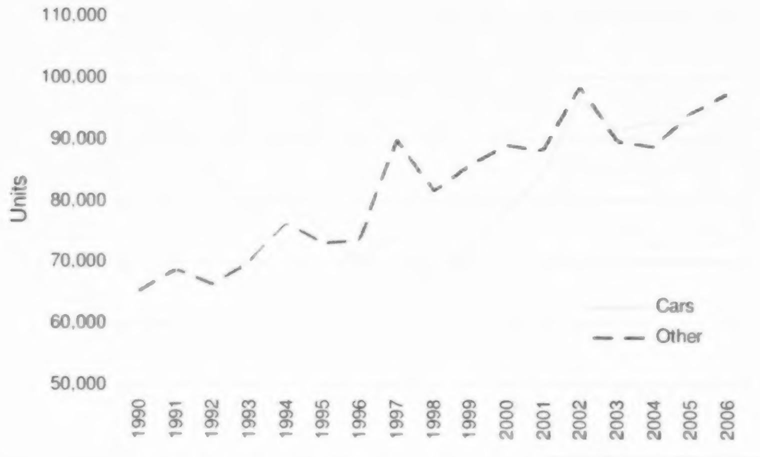
Data on kilometres driven came from CANSIM Table 405-0058 (Figure 20). Statistics Canada assembles the data from a representative sample of vehicle use logs collected using standard survey techniques.

Data on fuel prices came from CANSIM Table 326-0009 and driver registration data from CANSIM Table 405-0056.

Data on the number of licensed drivers in British Columbia were obtained from the Insurance Corporation of B.C.'s annual report series, B.C. Traffic Collision Statistics, available from *http://icbc.com/library/research_papers/traffic/index.asp* (downloaded January 2007).

Data on driver licensing in the United States came from the United States Department of Transportation, Federal Highway Administration (USDOT 2007), Unless another source is cited, the data used to calculate the statistics shown in this indicator came from the above sources.

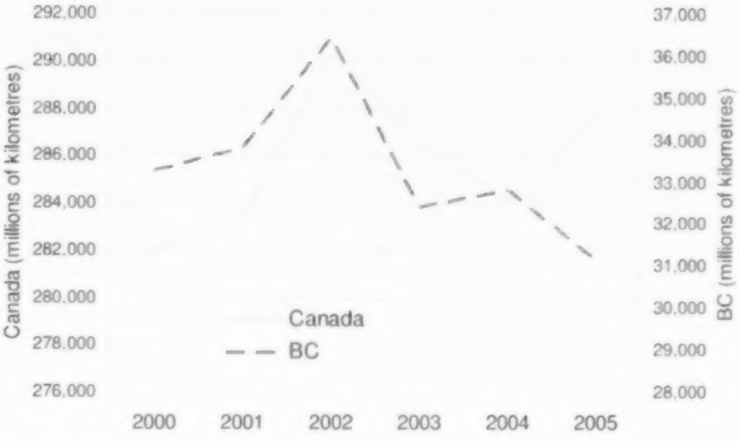
Figure 19. Number of new cars and other vehicles sold in B.C., 1990–2006.



Source: Statistics Canada CANSIM Table 079-0001. January 2007.

Note: "Cars" include regular passenger cars only. "Other" includes light trucks, minivans, SUVs, heavy trucks and vans, buses, and coaches.

Figure 20. Trends in kilometres driven in B.C. and Canada, 2000–2005.



Source: Statistics Canada, CANSIM Table 405-0058.

Note: Data are for light passenger vehicles (less than 4.5 tonnes gross vehicle weight), including all cars, SUVs, minivans and light pickups.

Interpretation

When new vehicle sales in B.C. were reported in Environmental Trends in B.C. 2002, sales of passenger cars had dropped to below 50% of the overall market (BCMWLAP 2002). The sales trend in B.C. during the 1990s was away from conventional cars and toward the light trucks category, which includes pickups, minivans, sport utility vehicles and, more recently, crossover vehicles. This shift meant that, despite a 5% improvement in fuel efficiency of the average new car between 1990 and 2002, the overall fuel efficiency of the average passenger vehicle actually dropped by 1% because more people were buying light trucks, SUVs, and other larger passenger vehicles (Environment Canada 2002). Since 2001 this trend appears to be reversing (Figure 19), and by 2006 passenger car sales were back up to 49.9% of all new vehicle purchases.

In both the car and light truck categories, the fastest growing market share is for smaller vehicles, with fuel-efficient, four-cylinder engines accounting for about half of new sales. It will take a decade or more, however, for today's fuel-efficient cars to replace the fleet of older, less fuel-efficient models now on the road.

The total distance driven by light passenger vehicles in B.C. also appears to be falling (Figure 20). Although total distance driven in B.C. and Canada peaked in 2002, the B.C. figure has continued to decline, while the Canadian figures rose again in 2005. The decline may be at least partly explained by a correlation with rising gasoline prices ($p = .07$) because Vancouver has among the highest urban gas prices in the country. The average price for gasoline was relatively stable from 2000 to 2002, but since then has risen from an average of about 70¢ per litre to as high as $1.10 per litre (in 2007) in Vancouver. Another reason could be the increasing population density in Vancouver's Lower Mainland, where construction of new high-rise buildings close to the city centre and transit routes has reduced the need to commute by vehicle.

Other statistics show a general decrease in automobile use in B.C. Despite the fact that the number of licensed drivers in B.C. increased from 2.75 million in 2000 to 2.91 million in 2005, the number of registered light passenger vehicles in B.C. dropped from 2.29 million in 2003 to 2.24 million in 2005. It is too early to say whether the drop in B.C. vehicle registrations is significant, but the provincial trend does not follow national registrations, which continued to increase during the same period.

In other areas, B.C. drivers also differ from other North American drivers. Using ICBC data for driver numbers and CANSIM registration data, calculations show that B.C. has a ratio of about 80 light passenger vehicles per 100 licensed drivers. No Canadian average was available, but in the United States, there are currently about 119 vehicles per 100 drivers (USDOT 2007). While the average American driver travels 22,600 km a year, adjusted for vehicle-to-driver ratio using data from USDOT (2007), calculations show that the average B.C. driver travels about half that distance, or only 11,200 km.

WHAT IS HAPPENING IN THE ENVIRONMENT?

The province has warmed since the 1950s, with the winter season generally experiencing the greatest increase in temperature. Warming since 1976, when the PDO last shifted to the warm phase, is evident over the whole province, and the rate at which temperature is changing is slowly increasing. Most of the province appears to have become dryer in winter and wetter in summer. There is some evidence that high-intensity rainfall events are becoming stronger and more frequent on the south coast. The ocean is slowly warming along the coast, and sea level is rising. Less snow generally lies on the ground in early April (although 2007 was an exception over much of B.C.), especially at elevations lower than about 1200 metres, and the warmer temperatures mean that spring runoff is coming earlier. Glaciers are generally retreating and losing mass over their annual cycle. Although the observed changes do not seem large, they have been accompanied by observable and in some cases, profound, effects on ecosystems, such as the devastating outbreak of mountain pine beetle in the interior of the province.

These changes have occurred because every year the concentrations of greenhouse gases from fossil-fuel combustion that largely drive these changes are increasing in the atmosphere. Greenhouse gas emissions in B.C. increased about 30% between 1990 and 2005, correlated with the growth in the provincial population.

Global climate models show that the increase expected in average global temperature is about 0.2°C per decade for the next two decades (IPCC 2007a). This short-term projection is close to the recent historical trend for British Columbia, which averaged an increase of 0.2–0.3°C per decade. By mid-century, a regional climate model for B.C. suggests that winters could warm by 2–3°C in the south and by 4–5°C in the north. Summers could also warm by 2–3°C. Regardless of the emission scenario used, all climate model projections suggest significant warming for the province by mid-century (see Pacific Climate Impacts Consortium climate overview at *www.PacificClimate.org*). Modelling suggests that for much of the province, winters will become marginally wetter and summers generally drier by the middle of the century. Extremes in temperature and, perhaps, precipitation events are likely to become more common.

The warming trend is also expected to continue through the last half of the century. Global climate models for the Pacific Northwest, using greenhouse gas emission scenarios corresponding to atmospheric CO_2e concentrations of approximately 620 and 860 ppm at the end of this century Baettig et al. (2007) project hotter conditions for the last 30 years of this century. These authors suggest that the B.C. region may experience 17 to 19 hotter summers and hotter years on average during the 2071 to 2100 period than occurred in the 1961 to 1990 period.

Examples of the effects and implications of climate change on this scale for British Columbia are many, complex, and sometimes surprising. Effects range from the direct effects of increasing temperature, such as a longer growing season, to possible changes to the geography of the landscape. For example, the frequency of large rockslides in northern B.C. appears to be increasing, partly as a result of increased precipitation and partly due to the thaw of mountain permafrost and the failure of steep rock slopes in response to glacier thinning (Geertsema et al. 2007). The following is a summary of some of the main effects.

- **Agriculture**: An increase in the length of the growing season would be favourable, but drier summers could limit crop production. Higher minimum temperatures, a longer growing season and fewer days of frost each year should improve the quality of grapes in the Okanagan (Caprio and Quamme 2002). However, for the Okanagan Valley as a whole, the projected crop water requirement could increase by 37% by the end of the century, making it likely that some water districts will be unable to meet the summer demand (Neilson et al. 2004).
- **Water Quality and Supply**: Changes in ambient air temperature, precipitation, and seasonal streamflow patterns are expected to affect water quality in inland freshwater rivers and streams. In general, rivers that get part of their water from snowmelt will see increased winter flow, earlier peak spring flow, and reduced summer flow as rising temperatures reduce the mountain snowpack. Such changes in timing of streamflow have already been observed in many streams and rivers throughout the Pacific Northwest (Hamlet 2006).

  Streamflow in low-elevation watersheds along the south coast responds directly to precipitation events and generally peaks in mid-winter. These basins are likely to be most affected by changes in October-March precipitation patterns. If winter precipitation increases, or precipitation intensity in individual storms increases, the annual and peak flows in such coastal basins would also change. The changes may mean an increase in the severity of floods and related impacts, such as erosion, damage to infrastructure, and loss of salmon spawn during periods of high river flow.
- **Pest Damage:** The range and impacts of insect pests and diseases, especially of forest trees, is expected to expand. The current mountain pine beetle outbreak in the interior of the province is a direct result of warmer winters that are no longer cold enough to kill the developing larvae (Safranyik and Carroll 2006). Vast areas of central B.C. pine forests have been killed and about 80% of the province's mature lodgepole pine are expected to die by 2013 (Eng et al. 2006). A disease of lodgepole pine, *Dothistroma* needle blight, is also expanding, causing extensive mortality of pine in the northwestern part of the province. In this case, a local trend of increasing summer precipitation appears to be responsible (Woods

et al. 2005). Climate change may also be favouring outbreaks of the Western spruce budworm in the interior Douglas-fir forests (Campbell et al. 2006).

Non-native pests are also expected to expand their range in the province. Insects such as the Asian gypsy moth, the Asian long-horned beetle, and the European wood wasp have the potential to spread in southern B.C., causing more damage as the climate warms (Hunt et al. 2006). The same is true of leaf and root diseases, such as sudden oak death (*Phytophthora ramorum*) and needle blights, which are likely to become more widespread in a warmer and wetter climate (Brasier 2005).

- **Salmon Fisheries:** Warmer river temperatures have serious implications for salmon, whose life cycle is adapted to cool and intermediate temperatures. Sockeye salmon migrate more slowly at temperatures above 18°C, and show increasing stress with higher temperatures. Chronic exposure to 21°C causes severe stress and early mortality. Such temperatures are now being experienced: the temperature in the Fraser River at Hope was above 21°C for several days in a row in 2004 (DFO 2007a).

- **Ocean Productivity**: The B.C. coast is affected directly by changes in the ocean conditions that affect fisheries, change the pattern of ocean currents, and have other effects. Every day, oceanic phytoplankton fix more than 100,000 tonnes of carbon in the form of CO_2, which is roughly half of the Earth's net primary production. Most of this carbon cycles within the ocean's food web, sinking downward as particles and returning upward in the form of dissolved nutrients. With global surface waters of the ocean now warming faster than the deep ocean, there is less vertical mixing and therefore a smaller supply of nutrients to the surface. Research shows that warming since 1998 has reduced the amount of carbon fixed in the ocean by a very small amount, probably because the nutrient supply has diminished (Behrenfeld et al. 2006).

  Over the 21 century, the acidity of ocean water is expected to more than double. As the ocean becomes warmer it becomes more acidic (increasing CO_2 leads to an increase in carbonic acid). Increased acidity erodes the calcium carbonate skeleton that protects many marine organisms, especially plankton (e.g., Riebesell et al. 2000). The increasing acidity also represents a threat to B.C.'s coral reefs.

  Studies show that dissolved oxygen is declining in deeper layers of water in the ocean. The summertime oxygen content in the layer 100 to 200 metres below the surface has declined slowly for at least the last 50 years. This is the result of decreased circulation of oxygen-rich waters from the surface, as the surface ocean waters become fresher and warmer faster than the deep ocean. Although not yet observed off the B.C. coast, low-oxygen water upwelling onto the continental shelf south of B.C. has sometimes caused massive marine mortality (DFO 2007b).

END NOTE

This background paper departs from the format of the other six papers that comprise the Environmental Trends in British Columbia: 2007 report in that the indicators section is not followed by sections about what is being done about the issue and what individuals can do. These areas are changing very rapidly as programs are being developed to address all aspects of climate change from adapting to the consequences of a changing climate to reducing emissions of greenhouse gases.

For the most recent information on what is being done and current links to initiatives, programs, and recommendations for action please refer to the webpages associated with this report. For more information, go to the B.C. Climate Change Secretariat website.

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Contaminants

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Contaminants

BACKGROUND

More than 23,000 chemicals are in use in Canada. Some are intended for controlled use in the environment (such as pesticides and water purification chemicals) and some may be released into the environment as byproducts (such as from burning wood and petroleum products) or accidentally through spills and leaks. Apart from pesticides and pharmaceuticals, which are regulated under other acts, more than 120 substances currently are either on the List of Toxic Substances (Schedule 1) of the *Canadian Environmental Protection Act*, 1999 (CEPA), or are considered by Environment Canada and Health Canada to have met the criteria for a toxic substance under CEPA. CEPA defines a substance as toxic if it enters, or may enter, the environment in amounts or under conditions that may pose a risk to human health or the environment. Substances are also considered to be toxic if any products formed as they break down in the environment meet this definition. These substances are listed either individually or as part of a group of substances that are considered to have met the criteria for a toxic substance. (A list is available from the National Pollutant Release Inventory at: *www.ec.gc.ca/NPRI-INRP-COMM//default.asp?lang=en&n=53E2467F*.)

The indicators in this paper were chosen to represent a spectrum of issues and consequences with respect to known contaminants in the environment. Indicators range from an estimate of how much chemical contamination is being released into the Canadian environment to trends in specific pollutants in food webs.

CONTAMINANT DEFINITIONS

In this paper, the term "contaminant" refers to substances, including those found naturally, that are present at concentrations above natural background levels, or whose distribution in the environment has been altered by human activity.

The term "pollutant" refers to a contaminant whose concentration in the environment is high enough to result in deleterious effects (GESAMP 1983).

Persistent Organic Pollutants (POPs)

Most of the indicators in this paper concern the group of substances known as persistent organic pollutants (POPs). They persist for a very long time in the environment because they resist being broken down by chemical and microbial processes. These chemicals have a variety of toxic effects, including disruption of hormone and immune systems of mammals. POPs include a wide variety of chlorinated and other halogenated chemicals, such as dioxins and furans, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), and other less well understood chemicals. They are fat soluble and accumulate in the fat reserves of organisms because they are resistant to being broken down metabolically. Through the process of bioaccumulation, such compounds become more concentrated as living organisms take them up and store them in body tissues faster than they can be broken down or excreted. When contaminated organisms are eaten by other animals, the compounds become more and more concentrated in the bodies of the predators. In a process called biomagnification, concentrations tend to increase at each step up the food web, often reaching high levels in the top predators. This means that POPs may accumulate in wildlife to concentrations that affect their health or risk the health of humans who consume them.

POPs were mostly used in industrial applications or are byproducts of incineration or other industrial processes; some were used as insecticides. As a group, POPs vary greatly in their toxicity, persistence in the environment, and how they are transported once they enter the environment. Many are now banned or are subject to stringent regulations controlling their use and release. After restrictions on their production and use came into effect from the 1970s onward, concentrations of several POPs in the Canadian environment decreased substantially. Because they resist chemical decomposition, however, the contaminants already in the environment continue to circulate and, for this reason, they are often referred to as legacy POPs.

The main groups of POPs discussed in this paper are PCBs, dioxins and furans, PBDEs, and DDT. The following notes are brief descriptions of each group of chemicals. Much more detail on chemistry, use, and regulation of these and other contaminants is available on Environment Canada websites.

- For PCBs, see the Waste Management Polychlorinated Biphenyls website: *www.ec.gc.ca/wmd-dgd/default.asp?lang=En&n=75C647A7-1*.
- For other substances, see the Management of Toxic Substances website: *www.ec.gc.ca/toxics/en/index.cfm*.

PCBs

Polychlorinated biphenyls (PCBs) are a class of stable, waxy to oily compounds that were used as heat-resistant coolants or insulators in electrical equipment, as plasticizers, solvents, and in several industrial processes. There are 209 different forms or congeners of PCBs. Congeners are variants on a common chemical structure; although related, they differ in toxicity and their fate in the environment. The PCBs sold and used commercially were mixtures of congeners.

Manufacture, import, and most non-electrical uses of PCBs were banned in North America in 1977 and it was made illegal to release PCBs to the environment in 1985. Canadian legislation allows PCB-filled equipment to be used until the end of its service life, but handling, storage, and disposal are subject to stringent government requirements. As a result of these measures, the quantity of PCBs in use declined by 54% between 1992 and 2003 (Environment Canada 2005). Most PCBs now enter the environment through leaks or improper disposal of waste oils and electrical equipment.

PCBs have a wide range of toxic effects. They affect the immune, reproductive, neurological, and endocrine systems of mammals, including causing cancer (Safe 1993). One group of about a dozen congeners are structurally similar to the highly toxic dioxin 2,3,7,8-TCDD and have similar effects on immune systems and fetal development. The toxic effects of other PCB congeners stem from their metabolic breakdown into highly toxic intermediate compounds that affect thyroid and vitamin A physiology.

Dioxins and Furans

The dioxins (polychlorinated dibenzo-p-dioxins) consist of a group of 75 congeners; furans (polychlorinated dibenzo-p-furans) are a group of 135 congeners. The most toxic dioxin congener, 2,3,7,8-TCDD, is the standard for comparing the relative toxicity of similar compounds (see text box, "Toxic Equivalents").

These compounds form as byproducts of industrial activities such as chlorine bleaching in pulp mills and incineration of waste. Dioxins and furans are structurally similar to PCBs and were also unintended contaminants of commercial PCB formulations and some herbicides. The 2,3,7,8-TCDD congener first appeared in sediments in the early 1960s when pulp mills converted to chlorine liquid bleaching.

Long-term exposure in mammals to 2,3,7,8-TCDD can affect reproduction, cause cancer and birth defects, damage the liver, and suppress the immune system (Environment Canada 1990). The US Environmental Protection Agency has classified 2,3,7,8-TCDD as a probable human carcinogen (ATSDR 1998). Because there is the potential for fish and shellfish to bioaccumulate dioxins and furans, people who eat large amounts of seafood may be at risk (reviewed in Ross and Birnbaum 2003).

TEFS & TEQS: TOXIC EQUIVALENTS

A system has been devised to estimate the combined toxic effect of the most common congeners of dioxins, furans, and PCBs. The system is based on the similarity between species in the physiological effects of toxicity. Each congener is assigned a toxic equivalency factor (TEF) relative to the most toxic dioxin (2,3,7,8-TCDD). The toxicity of a congener is calculated by multiplying its TEF by the concentration found in the environment to arrive at the toxic equivalent concentration or TEQ. The total toxicity of a PCB, dioxin, or furan mixture is estimated by summing the TEQs of the congeners.

PBDEs

Polybrominated diphenyl ethers (PBDEs) are widely used today as flame retardant chemicals in consumer products. One form used in polyurethane foam has been phased out, but others are added to plastics used in furniture upholstery, carpet backings, electrical insulation, computer and TV cases, and other consumer goods. PBDEs are less toxic than PCBs but are structurally similar and have similar environmental properties. They are generally soluble in fat and biomagnify within the food chain, but they are more susceptible to environmental degradation than PCBs. Mammalian toxicity of the 209 congeners of PBDEs is thought to increase as the number of bromine atoms in the molecule decreases (Gill et al. 2004).

The main source of PBDEs in the environment comes from consumer products during use and after disposal. PBDEs break down in water and sediment through microbial degradation and other processes (e.g., Gouin and Harner 2003). As PBDEs break down in the environment or in the tissue of animals they lose bromine atoms, which may transform them into more toxic, mobile, and bioaccumulative forms (research reviewed in Environment Canada 2006a). PBDEs enter the human body by ingestion or inhalation. They are suspected of causing cancer, decreasing thyroid hormone levels, and disrupting endocrine systems (McDonald 2002), causing liver toxicity, immune system effects (Gill et al. 2004), hyperactivity, and reproductive effects (Kuriyama et al. 2005).

Production of PBDEs ramped up during the 1970s. Three commercial mixtures of PBDEs have been manufactured: octaBDE, and pentaBDE, both of which were banned by the European Union (EU) and were discontinued in 2004 by the only North American manufacturer. The other mixture, decaBDEs, continues to be used around the world. Most (ca. 80%) is used in the plastics and electronics industry in the manufacture of circuit boards, wire coatings, and mobile telephone equipment. The remaining 20% of world use is for textiles, upholstery, cables, and insulation materials.

In December 2006, Environment Canada proposed the Polybrominated Diphenyl Ethers Regulations under CEPA, which would prohibit the manufacture of all PBDEs (none are currently manufactured in Canada) as well as the use, sale, and import of pentaBDE and two other less used forms, tetraBDE and hexaBDE (Canada, Department of Environment 2006). The proposed regulations do not ban the import or use of the most common mixture, decaBDEs, therefore a formal Notice of Objection has been filed by environmental groups.

Concentrations of PBDEs in animal tissue and human milk have been increasing steeply (Rahman et al. 2001; Hites 2004). In Canada, PBDEs have been found in human breast milk and blood, food, indoor and outdoor air, and water (Health Canada 2004a,b,c,d). A 2004 Health Canada study showed that Canadian women had the second highest concentrations of PBDEs in their breast milk in the world after women in the USA (Ryan 2004). Food represents the principal source of exposure for people, with breast milk accounting for 92% of the exposure for breast-fed infants (Ryan 2004; review of literature in Environment Canada 2006b). The effect of these residues in people, if any, is largely unknown.

DDT

The once commonly used pesticide DDT (dichlorodiphenyl trichloroethane) breaks down in the environment into DDE (dichlorodiphenyl dichloroethylene)—a highly persistent and endocrine disrupting chemical. DDE is produced in most animals when the body attempts to break down and excrete DDT; it was also a contaminant in DDT formulations. DDT was used in Canada to control biting insects and agricultural and forest pests from 1947 to 1969. It was banned after it was discovered that metabolites of the pesticide (mainly DDE) were bioaccumulating in tissue of predatory birds and causing egg-shell thinning and breakage. The use of DDT was banned in Canada in 1972 and its use is also currently prohibited in the United States and Europe. It continues to be used elsewhere in the world to control mosquitoes that carry malaria and on agricultural crops.

DDE residues from past pesticide use are still measurable in soil, sediment, and wildlife. These residues continue to be augmented by atmospheric transport of DDE from other continents where DDT is still in use.

ENDOCRINE DISRUPTING SUBSTANCES

Most of the POPs discussed in this report have endocrine disrupting properties in addition to other toxic effects. Endocrine disrupting substances (EDS) mimic or block vertebrate steroid hormones by interacting with hormone receptors in the body's hormone regulatory system. Typical effects include feminization of male animals or masculinization of females, eggshell thinning in birds, and disruption of vitamin A and thyroid hormone physiology in mammals. Although such effects were not suspected until research in the late 1980s began to raise questions, it is now a key area of research because of the health implications.

The EDS also appear to affect behaviour in many fish, mice, birds, and primates. Recent studies found changes in social and mating behaviour, increases in hyperactivity and aggression, impaired motor skills, and reduced ability to learn (Clotfelter et al. 2004; Zala and Penn 2004).

How Contaminants Move in the Environment

Contaminants enter the environment directly and indirectly through several routes. They may originate from a specific outlet ("point source"), such as a discharge pipe or smokestack from an industrial factory; they also may come from "non-point sources," which are the many and diffuse sources of pollutants, such as those carried off the land in urban or agriculture runoff or emitted to air from vehicle exhaust. They may also enter the atmosphere as vapours re-emitted from chemical residues already in the environment.

Once in the atmosphere, POPs can travel great distances before being deposited. They may be directly deposited on land or water by precipitation or on dust particles. The vapour form of contaminants may also enter water or snow through gas exchange processes. Once in the atmosphere, POPs travel on prevailing winds until the air masses reach cool regions, such as mountaintops and high latitudes, where the vapours condense into precipitation. The chemicals may accumulate in ice or snow until they are released into ecosystems through snowmelt and spring runoff (e.g., Li and Macdonald 2005). Many small lakes and reservoirs in the Rocky Mountains fed by glacial runoff contain concentrations high enough to affect wildlife at the top of the food chain (e.g., Hempel 2000).

ATMOSPHERIC TRANSPORT OF CONTAMINANTS IN SOUTHERN B.C.

A study to determine the relative contribution of global and local sources of air-borne PCBs and PBDEs found that deposition of air pollutants onto coastal waters is likely to be an important first step in the contamination of marine mammal food webs (Noel et al. 2007). The study analyzed air and rain data collected in high-volume air samplers at two sites over the course of a year (2004). One site was at Ucluelet, a remote location on the west coast of Vancouver Island exposed to global contaminants from the Pacific; the other was on Saturna Island in the Georgia Basin, close to local sources of contaminants from industry and urban centres.

The study found that deposition of the heavier congeners of PCBs and PBDEs (decaBDE) was higher at Saturna, indicating local sources of contaminants. There were significant concentrations of decaBDE in rain and in particulates in the air, showing that it is readily transported atmospherically. Although models that trace air masses flowing across the Pacific showed that Asia is an important source of air pollutants, there are also regional sources of contaminants. Further research is underway to better document the importance of local air pollution in B.C.

INDICATORS

1. Key Indicator: Total on-site discharge of toxic substances in B.C., 2002–2005

The weight of toxic substances released into the environment is a pressure indicator. It is a measure of the pressure or stress on the environment from human activities that release contaminants into the environment. This indicator shows the reported discharges of toxic substances listed in Canada's National Pollutant Release Inventory (NPRI).

Established in 1992, the NPRI now tracks release, disposal, and recycling of more than 300 pollutants by industrial, commercial, and institutional facilities. Legislated under the *Canadian Environmental Protection Act, 1999* (CEPA 1999), the NPRI requires companies to report annually to the government on releases and transfers of key pollutants. This information is available to the public in an annual report and through an online database. Polluters that meet specific reporting requirements (reporting thresholds) must report on the NPRI-listed contaminants they release. Reporting must identify any releases or transfers as waste whether to air, water, or land, injected underground, or transferred off-site for treatment, disposal, or recycling. Throughout this indicator, the term "total on-site discharge" will include both on-site releases and on-site disposal of contaminants.

THE NATIONAL POLLUTANT RELEASE INVENTORY

The NPRI list has been periodically restructured to incorporate more substances and different reporting thresholds. Since this indicator was last reported in 2002, the NPRI has adopted the following groupings of substances:

Part 1a: Core substances
Part 1b: Alternate threshold substances: This group includes heavy metals such as mercury, lead, and hexavalent chromium. These substances have lower reporting thresholds than the Part 1a substances (5 kg or 50 kg).
Part 2: Polycyclic aromatic hydrocarbons
Part 3: Dioxins and furans and hexachlorobenzene
Part 4: Criteria air contaminants
Part 5: Volatile organic compounds

For more information, the 2003 NPRI reporting guide is available at *www.ec.gc.ca/pdb/npri/2003guidance/guide2003/toc_e.cfm.*

Currently, anyone in Canada owning or operating a facility must report to NPRI if they fulfil both of the following criteria:

- They have employees working a total of 20,000 hours or more in the reporting year (or the facility was used for an activity to which the 20,000-hour employee threshold does not apply, such as biomedical waste incineration), and
- The facility manufactures, processes or otherwise uses any of the NPRI (Part 1a) substances in concentrations of 1% or higher and in quantities of 10 tonnes or more. The exceptions are NPRI substances considered to be byproducts, but the total weight of byproducts must also be included in the calculation of the 10-tonne threshold for each NPRI Part 1a substance. Certain substances have reporting thresholds lower than 10 tonnes.

Facilities that would report to NPRI include companies that make chemicals and chemical products, metal, mineral or rubber products, food products, textiles, electrical equipment, pulp and paper, cement. Companies involved in oil and gas extraction or mining and smelting activities report to NPRI, as do public utilities and companies with processes involving waste handling, incineration, wood preservation, printing, and other activities. Some types of facilities are exempt, such as educational and research institutions, vehicle repair shops, and those involved in growing and harvesting in the agriculture, forestry, and fisheries sectors.

Starting in 2000, facilities used for certain types of incineration and for wood preservation also reported to the NPRI whether or not they met the 20,000-hour threshold for working hours. In 2002 alternative thresholds were incorporated for cadmium, arsenic, lead, and hexavalent chromium. Requirements to report sulphur dioxide and 6 other criteria air contaminants (CACs) were added in 2002. More substances were added to the reporting list in 2003, including more volatile organic compounds, nonylphenol and related compounds. Starting in 2003, oil and gas wells and pumping stations were also required to report to NPRI, resulting in large increases in total number of facilities reporting. There were no significant reporting changes in 2004 and 2005.

This indicator deals with total on-site discharges of contaminants to the environment that are reported to NPRI as on-site releases and on-site disposal. These discharges can be unintentional (spills and leaks) or intentional releases (emissions to air from stacks, discharges to surface waters), or on-site disposal (to landfills, to underground injection) within the boundaries of the facility site.

Methodology and Data

Data for this indicator and the following supplementary information were obtained in early 2007 from Environment Canada's National Pollutant Release Inventory (NPRI): Communities Portal website at *www.ec.gc.ca/npri-inrp-comm/Home-WSBB01134D-0_En.htm* and from the NPRI database available through *www.ec.gc.ca/pdb/npri/npri_dat_rep_e.cfm.*

This indicator shows total on-site discharges (on-site releases and on-site disposal) reported to NPRI from 2002 to 2005 for British Columbia. Trends for earlier years are shown in Environmental Trends in British Columbia: 2002 (BCMWLAP 2002). They were not included here because there have been so many changes in reporting that totals for later years are not comparable with earlier years.

Most substances reported in this indicator are NPRI Part 1 substances; these are all reported in tonnes and account for most of reported substances. Sulphur dioxide, a Part 4 substance (criteria air contaminant), is included in the calculations with the Part 1 substances because of the large quantity that is discharged and its importance as an environmental contaminant. Other substances listed in Parts 2, 3, and 4 were not included because they are reported at different thresholds, such as kilograms, grams, or toxic equivalents, rather than tonnes.

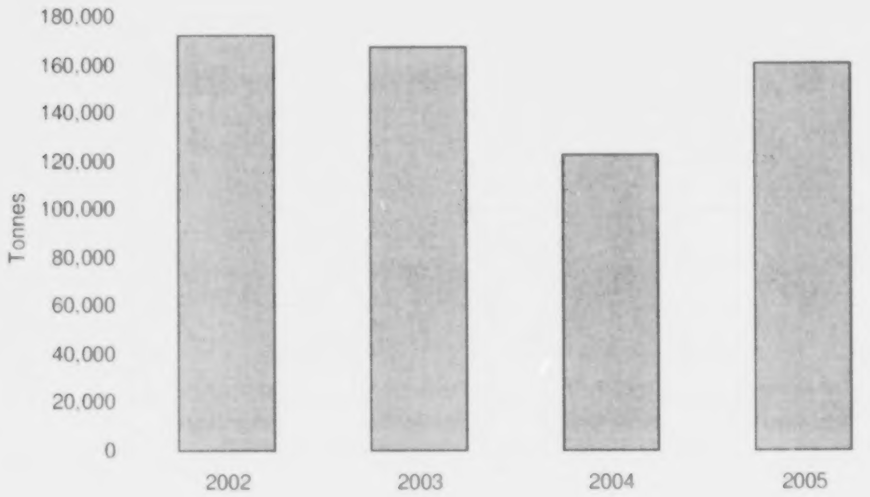
"Off-site discharges" includes pollutants transferred from a facility to another location, such as for disposal in landfill or for storage, application to land off-site, or injection underground off-site. Data on off-site discharges are shown in Table 1, but they are not added to the total on-site discharges shown in Figure 1 to avoid double counting. Because both originating and receiving facilities may be required to report to NPRI, some quantities would be double reported. For the same reason, substances sent off-site for recycling or to generate energy are not included in the Figure (see Figure 2 for hydrogen sulphide recycling data).

For NPRI reporting:

- Burial of wastes in an on-site landfill is reported as an on-site disposal. If an NPRI pollutant is transferred to an off-site landfill, it is reported as an off-site transfer for disposal.
- On-site land treatment is reported as an on-site release. It is also called land application farming, where the waste is incorporated into soil for biological degradation. This type of treatment method is usually approved under provincial jurisdiction.
- Underground injection is included as a method of on-site disposal for H_2S from acid gas extracted from natural gas. Subject to provincial regulation, these gases are injected into known geological formations at great depths, usually at the site of origin.
- Discharges to municipal wastewater treatment plants are reported as off-site transfers for treatment and are not included in the on-site figures.

Total on-site releases (including disposal) of NPRI substances are B.C. is shown in Figure 1 and Table 1.

Figure 1. Total on-site discharge (on-site release + on-site disposal) in B.C. of NPRI Part 1 substances plus sulphur dioxide, 2002–2005.



Source: The National Pollutant Release Inventory (NPRI), Environment Canada, 2007. *www.ec.gc.ca/pdb/npri/npri_dat_rep_e.cfm.*

Note: Lower figures in 2004 resulted from more hydrogen sulphide transferred off-site to be injected underground than in other years.

Table 1. Total on-site discharge (on-site release + disposal) of contaminants in B.C., 2001–2005 (in tonnes, rounded to nearest tonne).

Year	Air release	Water release	Land release	Total on-site release	On-site disposal	Total on-site discharges (releases + disposal)	Off-site disposal	Recycle	# of facilities
2002	62,797	14,657	0	76,154	96,116	172,270	2,258	879,021	389
2003	68,568	13,835	7	83,346	84,238	167,584	2,524	774,413	444
2004	74,693	13,734	36	88,470	34,239 *	122,709	51,347*	806,671	450
2005	71,909	13,539	50	85,506	74,656	160,162	11,849	851,338	466

Source: The National Pollutant Release Inventory (NPRI), Environment Canada, 2007. *www.ec.gc.ca/pdb/npri/npri_dat_rep_e.cfm.*

Note: Total releases may be greater than the sum of the releases by environmental medium, since releases of less than 1 tonne could be reported as undifferentiated total releases.

* In 2004 more hydrogen sulphide was transferred to off-site injected locations than in other years; total injected hydrogen sulphide, on- and off-site, remains similar each year.

No releases of Part 1 substances to land were reported for 2002. Because manganese is the major reported substance released to land, records for all facilities that reported manganese releases to land in 2005 were checked to verify that no releases were reported to land for 2002.

The 12 toxic pollutants released on-site in the largest quantities in B.C. between 2002 and 2005 were: ammonia, chlorine dioxide, hydrochloric acid, hydrogen fluoride, hydrogen sulphide, manganese, methanol, nitrate, styrene, sulphur dioxide, sulphuric acid and zinc (Table 2).

In 2005, the pollutants released in the largest quantities on-site in B.C. (Table 2) were:

- Hydrogen sulphide (74,225 tonnes, accounting for 46% of B.C.'s total), a flammable poisonous gas that is removed as an impurity by natural gas extraction facilities and injected underground into reservoirs.
- Sulphur dioxide (61,099 tonnes or 38% of the total), a toxic, colourless gas, used in pulp and paper mills, ore refining, and as a solvent. It irritates the respiratory system and plays a part in acid rain. The increasing quantities reported since 2002 likely come from the increasing number of new wells drilled and increased economic activity in other sectors, such as aluminum smelting.
- Ammonia (14,058 tonnes, just under 9% of the total), which is released as a colourless gas to air or in an aqueous solution to water by wastewater treatment facilities and, in lesser amounts, by pulp and paper facilities. Ammonia gas is extremely corrosive and irritating to the skin, eyes, nose, and respiratory tract. Exposure to high concentrations (above approximately 2500 ppm) is life threatening, causing severe damage to the respiratory tract, resulting in bronchitis, chemical pneumonitis, and pulmonary edema.
- Methanol (4,941 tonnes, about 3% of the total), a flammable poisonous liquid that is used during processing and manufacturing by the paper and allied products industry. It is also a

byproduct of this industry, formed during biological decomposition of biological wastes and sludge. The oil and gas industry also uses methanol to prevent the water in the gas from freezing in the pipeline. Methanol is not known to be carcinogenic but has short and long-term health effects.

Table 2: Total on-site discharge of selected toxic substances in B.C. (in tonnes, rounded to nearest tonne).

	Amount discharged (tonnes)			
Substance	2002	2003	2004	2005
Hydrogen sulphide	95,960	84,307	33,042	74,225
Sulphur dioxide	50,880	58,305	64,534	61,099
Ammonia	12,486	12,880	12,961	14,058
Methanol	5,692	6,241	5,701	4,941
Hydrochloric acid	2,095	1,814	1,609	1,745
Manganese	1,221	1,032	1,305	1,240
Nitrate	1,328	1,477	1,403	1,097
Styrene	410	524	534	746
Hydrogen fluoride	328	449	493	398
Zinc	229	264	277	256
Chlorine dioxide	116	150	146	181
Sulphuric acid	1,525	139	118	175
Total	172,260	167,582	122,123	160,161
# of facilities reporting	389	444	450	466

Source: National Pollutant Release Inventory, Environment Canada, 2007, *www.ec.gc.ca/pdb/npri/npri_dat_rep_e.cfm.*

In 2005, 466 facilities in British Columbia reported on-site release and disposal of 160,161 tonnes of toxic contaminants to the National Pollutant Release Inventory (NPRI). The number of facilities reporting increased from 389 in 2002 to 466 in 2005.

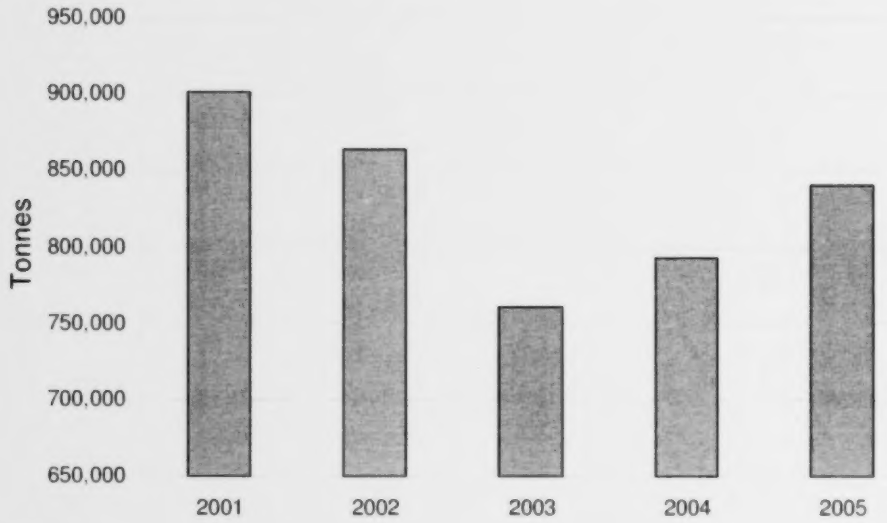
Since its inception in 1993 the NPRI reporting requirements have been continually adjusted and the list of substances expanded. In some cases, these changes result in reported increases in on-site releases even though facilities were not actually releasing higher amounts of contaminants than in previous years. For example, there was a sudden large increase in reported on-site releases in 1999 when 73 new substances were added to the NPRI. The 2002 to 2005 period was stable in terms of what substances were reported under Part 1.

The quantity of NPRI pollutants released to the environment does not show all pollutants entering the environment. Other substances, such as greenhouse gases, pesticides, and substances already scheduled for phase-out or that have been banned (e.g., chlorofluorocarbons and PCBs) are not included on the list. There are many smaller or non-point sources that release less than the reporting threshold of 10 tonnes. Such sources include cars and other vehicles, construction equipment, gas stations, dry cleaners, and other small facilities. The emissions from small facilities that do not meet reporting requirements may collectively account for the majority of releases of some pollutants. This shortcoming was partially addressed in 2000 when different thresholds were established for reporting some highly toxic substances that are usually released in small quantities. There are also natural sources, such as forest fires, that release pollutants into the environment, which are not captured.

Supplementary Information: Recycling NPRI substances

Part of the substances recorded as off-site transfers are sent for recycling, reuse or to be used as an energy source. Pollutants are sent off-site to recover solvents, acids and bases, metals and inorganic materials, for refining or reuse of used oil, and other recycling. In 2005 in British Columbia, more than 840,000 tonnes of hydrogen sulphide, which is a byproduct of the natural gas industry, were transferred off-site for recovery (Figure 2). Hydrogen sulphide is corrosive and is removed from the gas to meet safety and environmental protection requirements. For recycling, it is pelletized and made into sulphuric acid for use in fertilizer manufacturing, ore processing and oil refining, waste water processing, and other industries. Other substances that are recycled include copper, zinc, and lead.

Figure 2. Amount of hydrogen sulphide recycled in B.C., 2001–2005.



Source: The National Pollutant Release Inventory (NPRI), Environment Canada, 2007. *www.ec.gc.ca/pdb/npri/npri_dat_rep_e.cfm.*

Supplementary Information: On-site toxic substance releases in Canada in 2005, by province and territory

In 2005, British Columbia ranked fourth in Canadian jurisdictions in total reported on-site pollutant releases and disposal, accounting for about 12% of the Canadian total (Table 3).

Table 3. Total on-site releases and disposal of toxic pollutants in Canada 2005, by province and territory.

Jurisdiction	Total releases +on-site disposal (tonnes)	% of national total
Alberta	1,427,811.2	29.4%
Ontario	1,030,774.4	21.3%
Quebec	677,172.8	13.9%
British Columbia	576,172.7	11.9%
Manitoba	435,041.3	9.0%
Saskatchewan	269,053.9	5.5%
Nova Scotia	179,782.6	3.7%
New Brunswick	152,370.0	3.1%
Newfoundland	90,061.5	1.8%
NWT	8,903.6	0.2%
Nunavut	5,168.8	0.1%
PEI	2,659.4	<0.1%
Yukon	146.3	<0.1%
Canada	4,855,118.6	

Source: The National Pollutant Release Inventory (NPRI), Environment Canada, 2007. *www.ec.gc.ca/pdb/npri/npri_dat_rep_e.cfm.*

Notes: Figures include on-site releases to air, water, land, and underground. Waste transfers off-site for disposal, recycling, or reuse are not included.

2. Secondary Indicator: Trends in dioxin and furan levels in pulp and paper mill effluent, sediments, and Dungeness crab tissues

This is both a pressure and a response indicator. It shows the past pressure on the environment from dioxins and furans in pulp mill effluents and the results of the societal response by governments and industry to eliminate this pressure on the environment. The indicator addresses the questions: What is the impact of industrial pollutants released to the environment? Are efforts to protect the environment from industrial pollutants effective? This indicator has been reported in previous Environmental Trends and recently in greater detail in the B.C. Coastal Environment: 2006 report (BCMOE 2006), and is therefore summarized here.

When elevated dioxin and furan concentrations were found in fish and shellfish collected near coastal pulp and paper mills in the late 1980s, investigation showed that the chemicals were being generated as a byproduct of the pulp bleaching process. Both the federal and provincial government then introduced regulations to control dioxin and furan discharges. This indicator shows the effect of regulatory measures and changes in mill technology as industry complied.

Methodology and Data

Data for this indicator were collected under two federal programs:

- The Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations (1992), of the *Canadian Environmental Protection Act*.
- The Coastal Mills Dioxin and Furan Trend Monitoring Program.

In 1991, nine pulp and paper mills discharged secondary-treated effluent to B.C.'s coastal waters and were included in the monitoring program. Since then, some mills have closed and others have switched to bleaching technology that does not use elemental chlorine. By 2002, six mills and by 2004 only three mills required annual monitoring.

Results from sampling programs for effluent loadings of dioxin, dioxin and furan concentration in sediments near mill outfalls, and dioxin and furan concentrations in crab hepatopancreas tissue are shown in Figure 3. Due to the low levels, mill effluent monitoring for dioxin/furans is now conducted at 3-year intervals, so no new data were available for updating the graph.

Data tables for the graph and more details on methodology are reported in the Industrial Contaminants paper published as part of the British Columbia Coastal Environment: 2006 report (*www.env.gov.bc.ca/soe/bcce/02_industrial_contaminants/technical_paper/industrial_contaminants.pdf*).

Figure 3 illustrates the correlation between the steep decline in dioxin concentrations in mill effluents and the improvement in concentrations in local sediment and crab tissue.

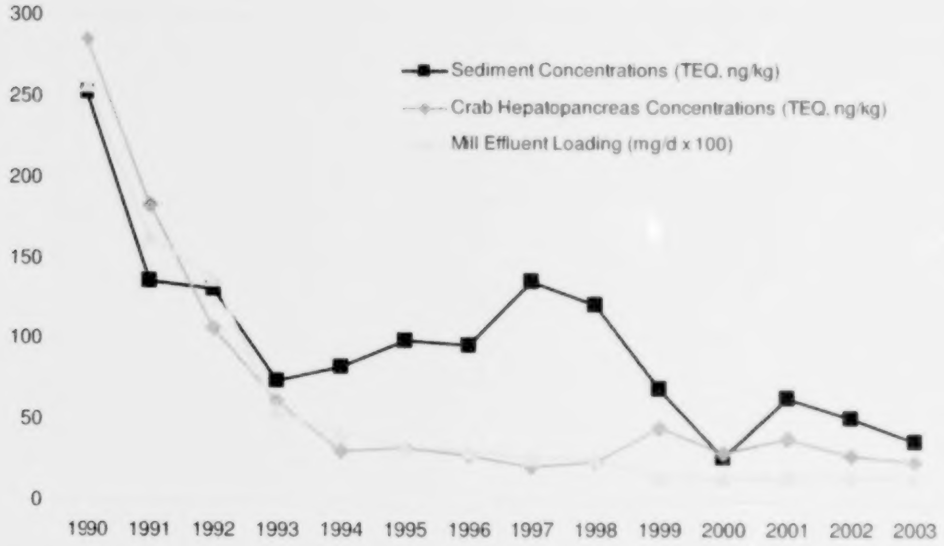
Changes in technology and processes brought about a 95% drop in total daily loading from all coastal B.C. pulp and paper mills for 2,3,7,8-TCDD in effluents. After 1999, 2,3,7,8-TCDD was not detectable in the effluent of any mills. At the same time, total daily loadings for the furan 2,3,7,8-TCDF also declined by more than 99% by 2004. Both substances are now present only in minute quantities that fall within federal discharge limits.

The improvement in effluent quality was reflected in a rapid decline in levels of dioxins and furans in the environment (sediments) and local organisms (crabs). Contamination in crabs near outfalls closely tracked the drop in concentrations in effluent. Contamination in sediment dropped, but not as rapidly as in crab tissue, in part because dioxins and furans have a strong affinity for sediments and break down very slowly.

This indicator shows that measures taken to eliminate this source of persistent contaminants in the marine environment have been effective. The continuing low, relatively stable, levels of dioxins and furans in sediments and crab tissue also show how persistent these chemicals are. It may also indicate that there is a continuing low level of input of dioxins and furans from other sources (e.g., regional incinerators and other local combustion, global atmospheric transport).

Unfortunately, given their persistence, low levels of dioxins and furans will remain in the environment for many years.

Figure 3. Total 2,3,7,8-TCDD loadings in pulp mill effluents from all mills reporting at each date, and dioxin and furan concentrations in sediments near the outfall and in crab hepatopancreas, 1990–2003.



Source: Pollution Prevention and Assessment, Environmental Protection, Environment Canada, 2005.
Note: Number of mills reporting: 9 mills for 1990–1997; 8 mills in 1998; 4 mills for 1999–2003.

3. Secondary Indicator: Cleanup of contaminated sites in B.C.

This is a response indicator showing a societal response to the problem of industrial contamination. It addresses the question: What is being done about environmental contamination?

An area is considered contaminated if the site is unsuitable for specified land or water uses. Such sites may have become contaminated through spills or through deposits of chemicals during the course of commercial and industrial activity. At some locations, toxic substances in soil, surface water, and groundwater are a threat to the environment and human health. Contaminated sites can release toxic substances into the surrounding environment, infiltrating the food chain, entering the groundwater, and contaminating neighbouring areas. Many sites were contaminated by past activities, up to a century or more ago, before the impact of such activities was known.

The contamination affects both land and water, and the size of contaminated sites ranges from less than a hectare to several square kilometres. The largest single source of site contamination in

B.C. has been activities related to fossil fuels and vehicles, such as petroleum and natural gas storage and distribution, and vehicle salvage and wrecking. Heavy metals such as lead, arsenic, cadmium, and mercury are also common at contaminated sites in B.C. Organic chemicals, including benzene and toluene from gasoline, occur at about two-thirds of the sites. Chlorophenols are found where wood treatment operations took place, as are benzo[a]pyrene and naphthalene from creosote. PCBs often occur at sites where heavy electrical equipment was used.

With the exception of federally managed sites, the B.C. Ministry of Environment is responsible for managing contaminated sites in the province. The Ministry ensures that site managers meet cleanup requirements to restore damaged lands to standards set out in the B.C. *Environmental Management Act*. The standards include requirements for protecting human health and improving ecosystem health by reducing or eliminating toxic materials and by performing other activities to return land to a condition suitable for more general use.

Methodology and Data

The B.C. Ministry of Environment has been collecting information on contaminated sites since 1988. The Contaminated Sites Registry was created in 1997 to provide public access to information on sites that are, or were, contaminated and the current status of the cleanup or remediation of the site. Not all of the sites entered in the Registry are necessarily contaminated: some were found to be clean after they were registered, and others were contaminated at one time but were remediated before being entered in the Registry. The Registry also contains sites awaiting complete assessment, for which the degree of contamination has not been determined.

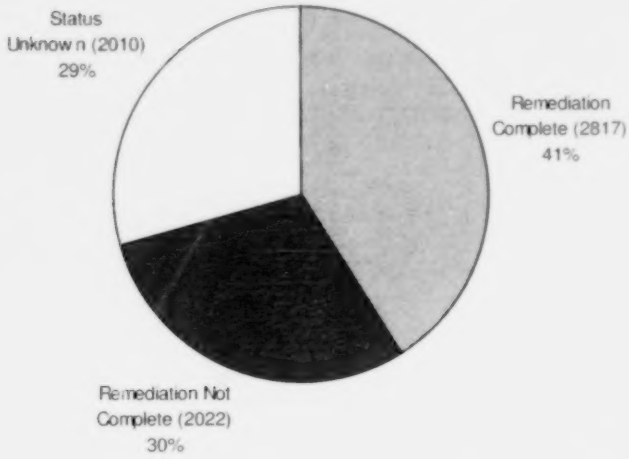
The Contaminated Sites Registry does not contain all contaminated sites in the province. Local governments, for example, can opt out of the registry program but must register a site if remediation is underway or if it is being decommissioned. Contaminated sites under federal jurisdiction (e.g., on federal Crown land) are also managed separately (see Supplementary Information, below); 268 of the federally managed sites in B.C. are included in the provincial Sites Registry.

For this indicator, the number of all contaminated sites was obtained from the Registry records. The proportion of the total sites was determined for which remediation is complete, in process, or for which a complete assessment is pending (Figure 4).

As of June 2007, 6,849 sites were registered in the whole province; 2,817 sites had been remediated and 2,022 were listed as actively under remediation. The remainder were contaminated sites for which assessment had not been completed.

More information on provincial contaminated sites remediation and regulation is available at *www.env.gov.bc.ca/epd/epdpa/contam_sites/.*

Figure 4. Remediation status of contaminated sites in B.C. recorded in the Contaminated Sites Registry.



Source: Data from Contaminated Sites Registry, B.C. Ministry of Environment, 2007.

Interpretation

There is no way to know how many, as yet unregistered, contaminated sites exist in the province. However, since the Ministry of Environment's Site Registry started, 41% of the known contaminated sites entered in the registry have been remediated and 30% are actively under remediation. In total, about 70% of the known contaminated sites in B.C. that were registered in the Sites Registry have met, or are in the process of meeting cleanup requirements under the B.C. *Environmental Management Act*.

Supplementary Information: Federal Contaminated Sites

The figures used in the indicator above do not include contaminated sites under federal jurisdiction, which are maintained in a separate federal contaminated sites inventory. Table 4 shows the status of federal contaminated sites in B.C. as of July 2007. The federal process of assessment, planning, remediation, and long-term monitoring is broken down into a 10-step process (for more information, see *www.ccme.ca/assets/pdf/ntnl_clssfctn_system_e.pdf*). The federal system does not use the same categories as the provincial SITE database, so the steps in the federal process that correspond to provincial categories are listed in the table.

Table 4: Status and number of B.C. contaminated sites in the Federal Contaminated Sites Inventory.

Status	Number of sites	Steps in federal process
Unknown/To be determined[a]	1368	Steps 1 to 6
Remediation not yet begun (includes sites for which a remediation plan is being developed)	112	Step 7
Remediation in progress (only sites for which a remediation plan is being implemented)	525	Steps 8 & 9
Remediation complete	131	Step 10
Total	2136	

Source: Federal Contaminated Sites Inventory: *www.tbs-sct.gc.ca/fcsi-rscf/*. Figures shown were current July 6, 2007; numbers change daily as reporting organizations update site data.

[a] Includes 204 records in "Highest step not reported" category.

As with provincial contaminated sites, the most common contaminants for sites providing this information are petroleum hydrocarbons and PAHs, heavy metals, metalloids (intermediate elements such as arsenic and selenium), and other metallic compounds. Soil is the most commonly contaminated media, followed by groundwater and sediment (CSMWG 1999).

4. Key Indicator: Long-term trends in persistent organic pollutants in bird eggs in B.C. (Great Blue Heron, Cormorant, Osprey)

This is a pressure indicator and also a response indicator. It shows the pressure on bird species from both the older persistent chlorinated pollutants (dioxins and furans, PCBs, pesticides) and from the more recently released polybrominated diphenyl ethers (PBDEs) in the environment. The trends in contaminant levels of the older compounds also show the effects of societal efforts to respond to the problem. It addresses the questions: What is the impact of persistent pollutants in the environment? Are efforts to protect the environment from industrial pollutants effective?

Trends in time and in regional environmental contamination, including contamination in other species, can be evaluated by measuring contaminant concentrations in eggs of birds. This indicator reports a summary of data compiled from monitoring programs for contaminants in bird eggs carried out by the Canadian Wildlife Service of Environment Canada, in some cases since the early 1970s.

The indicator compares toxic levels in eggs of three species of birds that use different habitats in several areas of British Columbia. Herons, cormorants, and osprey feed mainly on fish, therefore changes in the amount of contaminants entering the food chain rapidly show up in their prey and then in their eggs.

Methodology and Data

The Canadian Wildlife Service of Environment Canada (CWS) has been monitoring contaminant compounds in bird eggs since the 1970s. Compounds reported in this indicator are industrial organochlorines (PCBs, dioxins and furans, and PBDEs) and organochlorine pesticides (DDE, chlordane, dieldrin). For descriptions of the properties and sources of these compounds, see the introductory section of this paper.

The levels of contaminants in bird eggs were usually determined by the Environment Canada national laboratory using methods of the period. One exception is the PBDEs that were recently analyzed in archived samples by a private laboratory (Elliott et al. 2005). Not all contaminants were measured in each year or for each species. Unused portions of samples are maintained in a tissue bank, which facilitates analysis and retrospective trends to be assessed as new contaminants are identified. Specific methods for analyzing eggs are described in detail in Elliott et al. (1998, 2000, 2001, 2005); and Harris et al. (2003a,b, 2005).

The sum of PCBs is the sum of 31 to 51 PCB congeners, except for samples collected in early years where estimated PCBs were derived from relationships with measured Aroclor (Aroclor was a technical mixture of PCBs used until 1977). Concentrations of dioxin-like compounds (includes polychlorinated dibenzodioxins, PCDDs; polychlorinated dibenzofurans, PCDF; non-ortho PCBs) are presented as toxic equivalent concentrations (TEQs) on a wet weight basis using standard conversion factors for birds (Van den Berg et al. 1998). (Note: these TEQs are not comparable to data reported in Indicator 5 for marine mammals, which uses TEQs based on lipid weight.) PBDEs are the sum of 18 congeners, as listed in Elliott et al. (2005).

Great Blue Heron (*Ardea herodias*): Herons feed mainly on small fish, and changes in the amount of contaminants entering the food chain are rapidly reflected in contaminant levels in their prey, and later in their eggs. The coastal populations of herons are year-round residents although they move small distances between different seasonal preferred forage grounds. Contaminants in their eggs therefore reflect local conditions of the intertidal and estuarine forage sites near each colony. The CWS has monitored toxins in more than 20 Great Blue Heron colonies since the 1970s. Three colonies in the Georgia Basin were chosen for in-depth monitoring: a University of British Columbia colony, which reflects non-point source urban pollution; a Nicomekl colony, representing a rural habitat that should be less exposed to industrial contaminants; and a Crofton colony, chosen to reflect point-source pollution from a nearby pulp and paper mill (Table 5).

Double-crested Cormorants (*Phalacrocorax auritus*): Cormorants specialize on foraging prey (fish, crustaceans) from the waters and sea floor in the intertidal (littoral-benthic) zone. Contaminant levels in their eggs tend to reflect contaminant burdens in the sedimentary deposits in this zone. Cormorants are also resident birds, although their movements during non-breeding season may be over a somewhat greater distance than herons. CWS began monitoring toxins in Double-crested Cormorant eggs from the colony on Mandarte Island in the Georgia Basin in 1970 (Table 6).

Osprey (*Pandion haliaetus*): Osprey are a migratory species that winters in Mexico and Central America. Osprey return to nesting sites in the Pacific Northwest approximately a month before laying eggs. In that time they consume large amounts of fish from the local river systems, therefore, contaminants in their eggs largely reflect local environmental conditions. CWS monitored toxins in Osprey eggs from upstream and downstream of pulp mills located at Kamloops on the Fraser River and Castlegar on the Columbia River in the early and late 1990s (Table 7).

Figure 5: Contaminant trends in bird eggs in British Columbia from earliest sample year to most recent sample year (range 6-32 years).

	Dioxin-like compounds	PCBs	Chlordane	Dieldrin	DDE	PBDEs
Great Blue Heron	↓	↓ a	↓	↓	↓	↑
Double Crested Cormorant	↓	↓	↓	↓	↓	↑ a
Osprey	↓	↓	↓ ↑ b	↓	↓ a	↑

Note: (a) Contaminants increased mid-cycle of trend period; (b) chlordane levels increased in Osprey on Fraser River but decreased in Osprey on Columbia River to a much greater extent.

Tables 5, 6, and 7 report total PCBs, dieldrin, and DDE as presented in published papers, and dioxin-like compounds and sum chlordane values recalculated by summing averages reported in the published papers (details and references are in the table footnotes).

Table 5. Summary of contaminants in Great Blue Heron eggs in B.C., comparing concentrations in first year and most recent year of monitoring.

	UBC		Nicomekl		Crofton	
Contaminant	Year		Year		Year	
Dioxin-like compounds (TEQs ng/kg wet weight)	1983	208	1983	100	1983	495
	1998	58	1990	120	1994	44
Sum PCBs * (mg/kg wet weight)	1977	9.57	1977	1.67	1983	0.456
	1998	43.4	1999	0.312	1986	0.912
	2000	1.09			1994	0.435
DDE (mg/kg wet weight)	1977	2.82	1977	0.914	1983	0.333
	2000	0.359	1999	0.212	1995	0.102
Dieldrin (mg/kg wet weight)	1977	0.098	1977	0.029	1983	0.005
	2000	0.016	1999	0.013	1995	<0.0001
Sum chlordanes (mg/kg wet weight)	1977	0.102	1977	0.093	1983	0.018
	2000	0.038	1999	0.044	1995	0.018
PBDEs (µg/kg wet weight)	1987	12.5				
	2002	455				

Source: All data from Canadian Wildlife Service studies: Great Blue Herons: Elliott et al. 2001, 2005; Harris et al. 2003a.

Notes: Dioxin-like compounds: used column titled "estimated TEQs"; Sum chlordanes: summed averages for up to 5 of 6 chlordanes, when measured (includes: trans-nonachlor, cis-nonachlor, oxy-chlordane, cis-chlordane, heptachlor epoxide; does not include trans-chlordane).

* Three years of data are provided where there was a marked peak in contaminant levels between first and last year of monitoring. Data presented as geometric means.

Table 6. Summary of contaminants in Double-crested Cormorant eggs in B.C., comparing concentrations in first year and most recent year of monitoring.

	Mandarte Island	
Contaminant	Year	
Dioxin-like compounds (TEQs ng/kg wet weight)	1973	524
	1998	106
Sum PCBs (mg/kg wet weight)	1970	12.5
	2002	0.48
DDE (mg/kg wet weight)	1970	4.07
	2002	1.38
Dieldrin (mg/kg wet weight)	1970	0.040
	2002	0.007
Sum chlordanes (mg/kg wet weight)	1970	0.035
	2002	0.017
PBDEs [*] (µg/kg wet weight)	1979	0.24
	1994	385
	2002	62.5

Source: All data from Canadian Wildlife Service studies: Double-crested Cormorant: Harris et al. 2003b, 2005; Elliott et al. 2005.

Notes: Dioxin-like compounds: added 2 columns (Σ PCDD+PCDF TEFs and Σ PCB TEFs); Sum chlordanes: average of all 6 chlordanes.

[*] Three years of data are provided where there was a marked peak in contaminant levels between first and last year of monitoring. Data presented as geometric means.

Table 7. Summary of contaminants in Osprey eggs in B.C., comparing concentrations in first year and most recent year of monitoring.

	Upstream Kamloops		Downstream Kamloops		Upstream Castlegar		Downstream Castlegar	
Contaminant	Year		Year		Year		Year	
Dioxin-like compounds (TEQ ng/kg wet weight)	1991	25	1991	65	1991	28	1991	88
	1997	18	1997	13	1995	29	1997	35
Sum PCBs (mg/kg wet weight)	1991	0.366	1991	0.297	1991	0.612	1991	2.360
	1997	0.251	1997	0.199	1995	0.996	1997	1.240
DDE * (mg/kg wet weight)	1991	1.170	1991	1.650	1991	1.910	1991	1.820
	1997	1.190	1995	3.170	1995	1.010	1993	3.770
			1997	0.706			1997	1.100
Dieldrin (mg/kg wet weight)	1991	0.0001	1991	0.0007	1991	0.0026	1991	0.0044
	1997	0.0001	1997	0.0002	1995	0.00005	1997	0.0003
Sum chlordane (mg/kg wet weight)	1991	0.0016	1991	0.0028	1991	0.0365	1991	0.0358
	1997	0.0038	1997	0.0044	1995	0.019	1997	0.0096
PBDEs (µg/kg wet weight)					1991	18.4	1991	7.84
							1997	195

Source: All data from Canadian Wildlife Service studies: Osprey: Elliott et al. 1998, 2000, 2005.

Notes: Dioxin-like compounds: TEQs calculated using averages of 2378-TCDD, 12378-PnCDD, 123678-HxCDD, 1234678-HpCDD, OCDD, 2378-TCDF, 23478-PnCDF and CBs 77, 126, 169, 118, 105. Sum chlordanes: summed average of r-chlordane (includes trans-nonchlor, cis-nonachlor, oxychlordane, trans-chlordane, cis-chlordane) and average of heptachlor epoxide.

* Three years of data are provided where there was a marked peak in contaminant levels between first and last year of monitoring. Data presented as geometric means.

PCBs, dioxin-like compounds: Monitoring shows that concentrations of PCBs and dioxin-like compounds have decreased in heron eggs since their use was banned or restricted in the late 1970s through the early 1990s (Table 5). The Crofton heron colony was the most contaminated by dioxins and furans, which were coming from the nearby pulp and paper mill. The drop in egg contamination coincides with changes in pulp mill technology in the 1990s that eliminated these contaminants from effluent (see Indicator 2: Trends in dioxin and furan levels in pulp and paper mill effluent). The UBC colony, which forages in the Fraser River estuary, showed high exposure to PCBs, which likely originated from a variety of non-point and point sources in the urbanized region. Over the years, the decline in PCBs in bird eggs has occurred reflecting changes in ambient environmental levels. The lower levels of all contaminants in eggs from the

Nicomekl colony are consistent with what would be expected for a rural colony away from direct urban or industrial influence.

The Double-crested Cormorant colony at Mandarte Island show a similar history of declining concentrations of PCB and dioxin-like compounds measured in eggs (Table 6).

Over the 1990s the PCB levels in Osprey eggs have declined along both riverways (Table 7). PCBs are likely higher in the Columbia than in the Fraser River Basin due to extensive hydroelectric generation and related industries (PCBs were used in electrical insulating fluids until the early 1970s). PCBs burdens in Osprey in the late 1990s are much lower than levels measured in herons at UBC during the same time period (50–100fold). Dioxin-like compounds in Osprey eggs collected from the Fraser and Columbia River Basins decreased substantially between 1991 and 1997. This decline was most evident downstream of pulp mills, such as the areas downstream of Kamloops and Castlegar. Again, levels are much lower than concentrations observed in the herons/cormorants in the Georgia Basin.

PBDEs: The bird egg monitoring shows the recent and increasing threat from PBDEs in the environment with concentrations increasing rapidly. Mean concentration of PBDEs was 455 ng/g wet weight in the heron eggs from the UBC colony in 2002. At some locations, concentrations of the most toxic PBDE congener (penta-dibromodiphenyl ether) in fish are approaching levels potentially toxic to fish-eating birds (Elliott et al. 2005). Although production of the octa- and penta- mixtures of PBDEs was banned by the European Union and voluntarily discontinued by the only North American manufacturer in 2004, the decaBDEs are still in use. Recent regulations proposed in Canada would ban manufacture of all PBDEs, including decaBDEs, but would not ban the import of decaBDEs.

Organochlorine pesticides: Monitoring shows that overall concentrations of DDE, dieldrin, and chlordane in herons, cormorants and osprey have been declining over time since regulations banning their use were implemented. As with the industrial contaminants described above, there are local differences in concentration, with the greatest concentrations of those pesticides found in cormorant eggs from Mandarte Island and heron eggs from UBC. All of these pesticides were used in urban environs for insect control, but the predominant source was most likely commercial upstream agricultural activities. The variable levels of DDE in Osprey suggest exposure may have occurred outside of the breeding grounds because there are no evident local sources.

In birds, the impact of organochlorine pesticides is apparent in thinner eggshells, which are easily damaged, lowering reproductive success. Shell thickness has increased at all three heron colonies (UBC, Crofton, and Nicomekl) since 1987 (Harris et al. 2003a), which coincides with the reduction in use of these pesticides. Permits for most uses of chlordane were suspended in 1985; use as a termite control was discontinued in 1995. The sale of dieldrin was heavily restricted in the mid-1970s, with its last registered use in Canada in 1984.

Interpretation

Long-term monitoring of contaminants in bird eggs shows that, in general, overall levels of the older, so-called legacy POPs have decreased in the environment since the 1980s. This is consistent with efforts to phase-out and eliminate these compounds, which began in the late 1970s and became more stringent in the 1980s and 1990s. The continued presence of these compounds in eggs, however, and the fact that in some cases concentrations are quite variable among individuals many years after they are no longer used in Canada, shows the very long persistence of the chemicals in the environment and the ongoing atmospheric deposition of compounds (Wilson et al. 1996). Although DDT was banned in Canada in 1969, the breakdown product DDE is still present in wildlife at toxicologically significant concentrations. These residues likely come from atmospheric transport from regions where DDT is still used for insect control, as well as from persistent residues in B.C. soils and sediments from past agricultural use.

The rapidly increasing contaminant level of a newer class of compounds, the PBDEs, reflects the widespread use and release of these compounds since the 1970s when production began to expand. Limited phasing out of PBDEs began in 2004, with the voluntary restriction of some groups of congeners. One group, the decaBDEs, is still in use around the world. It is not known what effect the toxicity from these chemicals may be having on birds, especially in combination with other stressors such as loss or degradation of habitat.

5. Secondary Indicator: Persistent organic pollutants in tissues of marine mammals on the B.C. coast

This is a pressure indicator. It shows the accumulation of persistent contaminants in killer whales and harbour seals. It addresses the question: What is the extent of contamination from persistent organic pollutants (POPs) in the coastal environment? A summary of recent data for this indicator is presented here; for greater detail and data on other species, see the British Columbia Coastal Environment: 2006 report (*www.env.gov.bc.ca/soe/bcce/*)

Persistent organic pollutants (POPs) enter the marine food chain when organisms at the bottom of the food web, such as plankton, accumulate the contaminants from water, sediment, and food. POPs are fat soluble and persistent; therefore, through biomagnification, the tissue contaminants become more concentrated as they move up the food chain to seals and killer whales.

This indicator reports on levels of POPs in harbour seals (*Phoca vitulina*) and three groups of killer whales (*Orcinus orca*) inhabiting the B.C. coast—transients and the southern and northern populations of resident killer whales. The transient whales are predators on other marine mammals, whereas both resident whale populations eat mainly fish. Because killer whales travel over a large area and feed on salmon that are thought to accumulate contaminants from their time at sea, contaminants found in their tissues may reflect the general state of contamination in the Pacific Ocean ecosystem.

In contrast, harbour seals are year-round residents on the coast and occupy relatively small ranges of about 20 km^2 (Cottrell et al. 2002). This makes them better indicators of contamination at a local to regional scale. Stocks of two of their preferred food fish, herring and hake, however, do undertake local migrations, so there may be some sources of contaminant from sources outside the harbour seals' immediate range (Ross et al. 2004).

Methodology and Data

Killer whale samples: Blubber samples were collected with biopsy darts from killer whales of both sexes and various ages in the three coastal populations. PCBs, dioxins, and furans were analyzed using high-resolution gas chromatography/high-resolution mass spectrometry (Ross et al. 2000). A slightly different grouping drawn from the same original sample set was analyzed later for PBDEs (Rayne et al. 2004). The identity of each individual sampled was confirmed using a photo identification database containing all resident and many transient whales. This provided demographic information and ensured that the same whale was not sampled twice.

Harbour seal samples: Tissue samples from harbour seal pups were collected in 1996 from four locations in the Strait of Georgia (Victoria, Vancouver, Crofton, and Hornby Island) and from Queen Charlotte Sound. The concentration of POPs in harbour seals increases with age, especially in males. Therefore, by sampling only pups, researchers could ensure that subjects were all the same age (3 to 6 weeks) and that virtually all of the contaminants carried by pups come from their mothers through the placenta and in milk (Ross et al. 2004).

Total PCBs and total PBDEs in blubber of killer whales of various ages and harbour seal pups are summarized in Table 8 and shown in Figure 6.

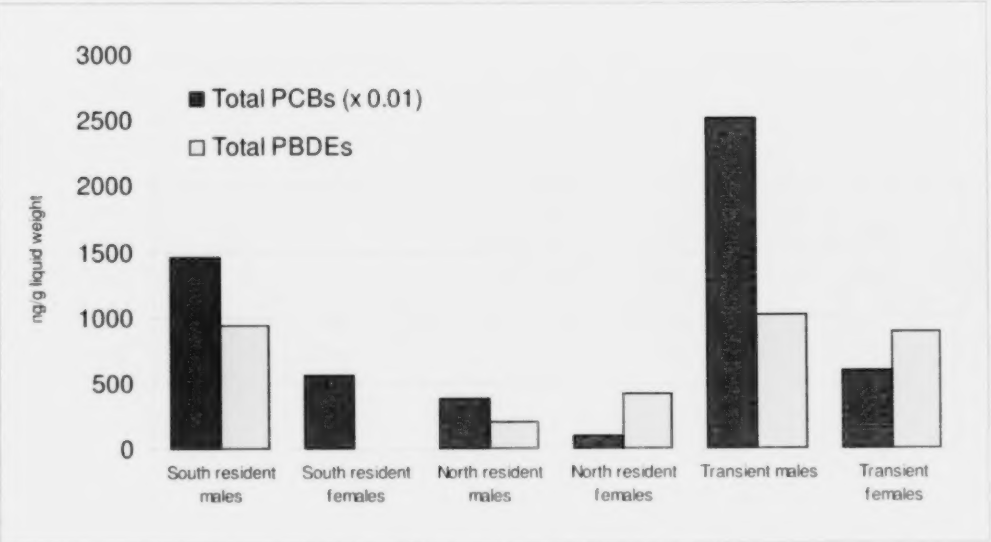
Table 8. Total PCBs and PBDEs in the blubber of killer whales of various ages and harbour seal pups (3–6 weeks old) on the coast of B.C.

		Total PCBs (ng/g)		Total PBDEs (ng/g)		
Species	Population sampled	Mean (n)	SD	Mean (n)	SD	Data source
Killer whale	S. resident males	146,300 (4)	32,700	942 (5)	291	PCBs: Ross et al. 2000 PBDEs: Rayne et al. 2004
	S. resident females	55,400 (2)	19,300	–	–	
	N. resident males	37,400 (8)	6,100	203 (13)	58	
	N. resident females	9,300 (9)	2,800	415 (8)	338	
	Transient males	251,200 (5)	54,700	1,015 (6)	302	
	Transient females	58,800 (5)	20,600	885 (7)	353	
Harbour seal (pups)	Strait of Georgia	2,475 (31)	174	–	–	Ross et al. 2004
	Queen Charlotte Sound	1,143 (5)	262	–	–	

Notes: Concentrations are in ng/g (ppb) lipid weight. PCB data on whales are for adults only; PBDE data for whales include some juveniles.

Large variances about the means (SD = standard deviation) are due to the wide age range in whales sampled as well as the small sample sizes.

Figure 6. Total PCBs and PBDEs (ng/kg lipid weight) in the blubber of killer whales of various ages on the coast of B.C.



Sources: Compiled from Ross et al. 2000 and Rayne et al. 2004.

Interpretation

Of the three B.C. groups of killer whales tested, PCB concentrations were the lowest in the northern resident whales and highest in the transient population. Although the two groups of resident whales have a similar diet, the more contaminated southern population likely eats more contaminated fish from the industrialized areas of B.C. and Washington state (Ross et al. 2000). The health risk to killer whales of this concentration of contaminants is not known, but they are among the most contaminated marine mammals in the world (Ross et al. 2004). A high tissue concentration of PCBs was one reason for the recent classification of southern resident killer whales as Endangered under Canada's *Species at Risk Act*.

Of the three groups of harbour seal pups tested for PCBs, those born in Puget Sound were the most contaminated and those from Queen Charlotte Sound the least contaminated (Ross et al. 2004). This is consistent with the finding that herring from the Southern Strait of Georgia have lower contaminant concentrations than herring from the central and southern portions of Puget Sound (O'Neill and West 2005). The contamination in the diet of adult harbour seals is likely reflected in regional differences in contamination of their pups.

The studies cited show that PCB concentrations in killer whales are roughly 100 times higher than PBDE concentrations (Rayne et al. 2004), which likely reflects the earlier period of use of PCBs relative to PBDEs. PCBs may also accumulate to a greater extent because PCB molecules are smaller than PBDE molecules, and small size favours more rapid uptake. The most common PBDE congener, BDE-47 (one of the more toxic forms), accounted for about 60–75% of the PBDEs found in killer whales (Rayne et al. 2004) and is widely distributed in environmental samples (Gill et al. 2004). In all three killer whale populations, males were more contaminated with PCBs (but not PBDEs) than females. This is consistent with the fact that females shed some of their body burden of PCBs and related compounds through the birth and lactation of each calf, whereas males would continue to accumulate contaminants throughout their lives. The lack of difference between males and females for PBDEs may reflect a barrier in females that prevents ready transfer to their calves (Ross 2006).

Although the health risk to whales from these contaminants is unknown, concentrations in most whales were higher than those likely to cause immunotoxicity in harbour seals (Ross et al. 2000). The burden of mixed contaminants has been shown to impair the immune system in seals (de Swart et al. 1996). Research has shown that Vitamin A and thyroid hormone physiology in harbour seals in the Strait of Georgia and Puget Sound have been affected by exposure to contaminants (Simms et al. 2000; Mos et al. 2006, 2007; Tabuchi et al. 2006). Contaminant concentrations in Strait of Georgia seals are still below those likely to cause immunotoxicity (Ross et al. 2004).

Overall, this indicator shows that POPs released into the environment continue to accumulate through the food webs and recycle in ecosystems long after measures intended to curtail emission from industrial sources have taken effect. It shows that PCBs, which have been the target of regulation and pollution control efforts for decades, are still accumulating in whale and seal tissues. Adding to the tissue contamination of the earlier "legacy" POPs are the PBDEs, which appear to have been accumulating within the marine food chain since the 1970s. They have emerged only recently as an environmental concern, in much the same way that PCBs were considered 30 years ago. Recent research suggest that it may take up to 60 years before southern resident killer whales are likely to experience a real reduction in health risks associated with PCB exposure (Hickie et al. 2007).

6. Key Indicator: Trends in pesticide use by professional landscape services in the Lower Mainland of B.C.

The quantity of pesticides applied to landscapes is a pressure indicator. It shows the total weight of pesticide active ingredients used in the Lower Mainland by professional landscape services.

Pesticides are materials or microorganisms that are used to prevent, destroy, repel, or otherwise reduce pest populations. The term "pesticides" includes insecticides and insect repellents, herbicides, fungicides, rodenticides, wood preservatives and anti-sapstain chemicals, slimicides (biocides used in cooling towers and papermaking) and other compounds. Pesticides registered for use in Canada include a wide variety of active ingredients and modes of action. These range from high toxicity, persistent compounds to low-toxicity and non-toxic substances and microorganisms (microbial products).

It is an accepted international goal to reduce risks to human health and the environment from pesticide use (c.f., OECD/FAO 1998); the British Columbia government has been actively promoting this objective since 1991. Risks to human health from use of pesticides can occur for pesticides applicators, farm workers, bystanders, consumers (e.g., of agricultural commodities), and site users (e.g., in lawns and landscapes). Environmental effects include harm to nontarget organisms, such as beneficial insects, birds, and other wildlife, as well as contamination of air, water, or soil.

Because of the wide differences in the various properties of substances used as pesticides, there is not complete agreement on the best way to measure progress in reducing impacts. In 1991, B.C. chose to compile records on each pesticide active ingredient separately because it would permit tracking of individual active ingredients and provide data that could be aggregated later if needed for further analysis.

Methodology and Data

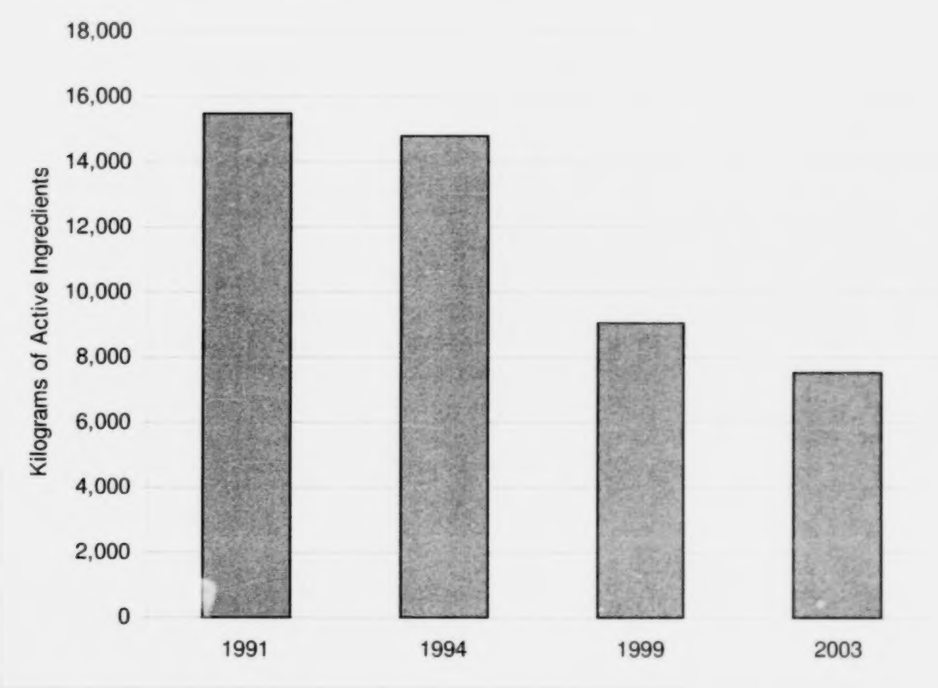
The data for this indicator came from a series of four studies of all pesticide sales and use in British Columbia. The studies were conducted in 1991, 1995, 1999, and 2003 in partnership between the B.C. Ministry of Environment and Environment Canada. The complete reports, including original data tables for the 1995, 1999, and 2003 studies are available online at *www.env.gov.bc.ca/epd/epdpa/ipmp/tech_reports.html*.

This indicator reports an analysis of a subset of the data: annual summaries of pesticide use from all Lower Mainland British Columbia businesses with licences to use pesticides in the landscape category (e.g., lawn services, landscapers). This subset of data was chosen because it was the most complete, and the accuracy of the records was evaluated for each of the four years. It is also an area of pesticide use that is of particular concern to the public.

Complete records (called Service Licence Use Summaries) are available from licensed pesticide services because each service must submit an annual summary of pesticide use to the B.C. Ministry of Environment as a condition of renewing their licence to conduct a business involving pesticides. The only exceptions are those businesses that do not require a licence because they use only pesticides classified as Excluded under the *Integrated Pest Management Act* Regulation (previously classified as Exempted under the B.C. *Pesticide Control Act* Regulation). Excluded pesticides are generally of low-toxicity, such as insect repellents, insecticidal soap, corn gluten meal herbicides, boron compounds, and swimming pool chemicals. For all Non-Excluded pesticides, service licence holders must keep a daily record of the pesticides used and the quantity.

Service Licence Use Summaries show the name of each pesticide and the quantity used. This information was used to calculate the weight of each active ingredient used that year. Sources of error and irregularities on the summaries were identified, followed up with the licensees, and corrected where possible (for detailed analyses of sources of error, see the original reports). In the 2003 study, only 6 (3%) of the 188 Service Licence Use Summaries submitted contained errors.

Figure 7. Total pesticide active ingredients (in kg) used by Lower Mainland B.C. pest control services licensed in the landscape category, 1991–2003.



Source: B.C. Ministry of Environment and Environment Canada pesticide surveys (1991, 1994, 1999, 2004).

The following trends were identified:

- The use of pesticides by landscape services showed a statistically significant decrease of 50% between 1991 and 2004. Over the 4 years, total weight of active ingredients used dropped from 15,468 kg in 1991 to 7,541 in 2003 (Table 9).
- The largest decreases in 2003 among the top 20 pesticides were mineral oil and the herbicide glyphosate. Use of insecticidal mineral oil varies widely from year to year and therefore the decrease was not statistically significant.
- Over the span of 12 years, several pesticides disappeared from records as they were discontinued (see text box "Phasing Out Toxic Home and Garden Pesticides"). These included the insecticide methoxychlor and the herbicide paraquat, which was among the top 20 pesticides used in 1991.
- Use of other registered pesticides used in 1999 ceased entirely by 2003. Among these were sodium metaborate tetrahydrate and sodium chlorate, which are formulated in certain herbicide products, and the fungicide bromacil.

- The use of chlorothalonil (a turf fungicide) increased between 1991 and 2003 and use of quintozene (another turf fungicide) increased between 1991 and 1999, but dropped off in 2003. Since these fungicides are used for turf diseases that spread in humid conditions, such variability reflects differences in weather from one season to the next, as well as changes in registrations and use patterns.
- The top 20 list included two new, least-toxic active ingredients that were not sold in early years: two herbicides, acetic acid and fatty acid.

Table 9. Top 20 active ingredients used by Lower Mainland B.C. pest control services licensed in the landscape category, 1991–2003

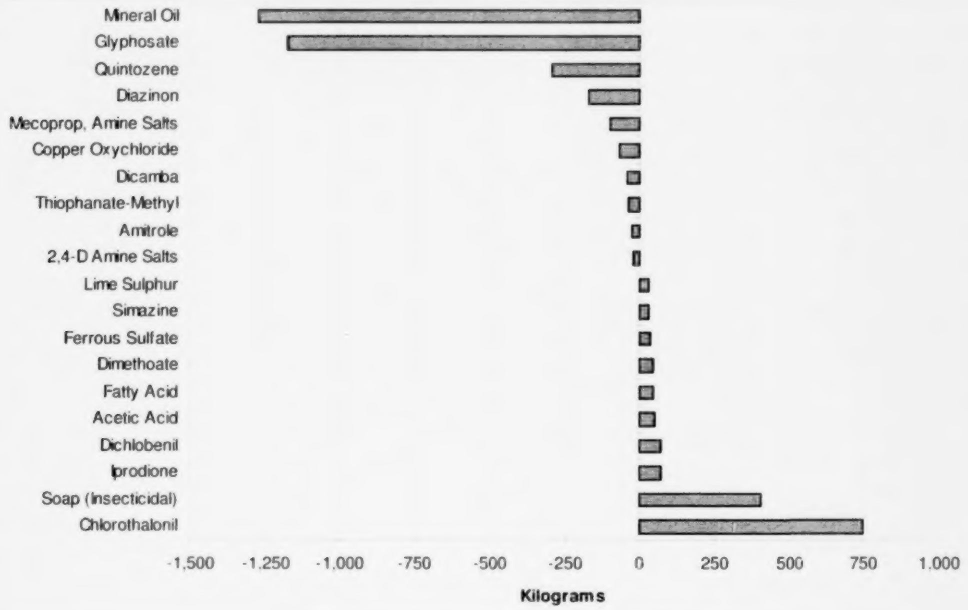
	Total used (kg)				
Active ingredient	1991	1995	1999	2003	Change from 1991 (kg)
Mineral oil (insecticidal or adjuvant)	2,443	4,183	1,342	1,171	−1,272
Glyphosate	2,145	1,068	1,084	968	−1,177
2,4-D amine salts	921	1,088	863	899	−22
Diazinon	676	539	639	507	−169
Mecoprop, amine salts	669	903	567	569	−100
Quintozene	468	371	794	175	−293
Dichlobenil	394	636	452	464	+70
Lime sulphur	328	379	428	300	+28
Soap (insecticidal)	314*	359	1,031	654	+403*
Dicamba	140	204	129	100	−40
Copper oxychloride	132	146	74	62	−70
Thiophanate-methyl	93	40	30	58	−35
Amitrole	91	47	44	64	−27
Iprodione	50	62	128	124	+73
Simazine	41	94	77	74	+32
Chlorothalonil	28	72	371	774	+748
Fatty Acid	0	38	67	46	+46
Ferrous sulphate	0	82	65	36	+36
Acetic acid	0	0	0	51	+51
Dimethoate	0	0	0	45	+45
Total	15,468	14,802	9,071	7,541	−7,954
Number of licensed services	200	235	189	162	−38

Source: B.C. Ministry of Environment and Environment Canada pesticide surveys (1991, 1994, 1999, 2004).

Note: Values from source table are rounded to nearest whole number.

* Error in 1999 report on quantity of insecticidal soap in 1991 has been corrected in this table.

Figure 8. Change in the top 20 active ingredients used by Lower Mainland B.C. pest control services licensed in the landscape category, 1991–2003



Source: B.C. Ministry of Environment and Environment Canada pesticide surveys (1991, 1994, 1999, 2004).

Interpretation

As an indicator of trends in pesticide impacts, the total weight of active ingredients used has the benefit of being a relatively accurate measurement. The main drawback is that the large number of substances registered as pesticides includes those that are very toxic in small quantities as well as those that are low toxicity, thus their impacts are not all comparable on a weight basis. For example, if someone switches to using a higher toxicity product, the total weight of active ingredient used decreases, but the environmental impact could increase. If a heavier, but lower toxicity active ingredient, such as horticultural oil, replaced a more toxic chemical, the weight used would increase, but the environmental impact could be less.

When interpreting pesticide use data, it is also important to realize that pesticide use patterns can depend on weather conditions, pest populations, cost and availability of products, changes in registration status, and other factors. For example, fungicide use on turf in coastal areas depends on rainfall and humidity patterns, which can vary widely from year to year. Also, the status of products for landscape use continues to change as registrations are withdrawn or cancelled. Since 1991, several of the most toxic active ingredients have disappeared from the market (see text box).

The results in this indicator may underestimate the total weight of Excluded pesticide use. This is because Excluded pesticides are listed in the B.C. regulations as pesticides that can be used by landscape businesses without the need to obtain a licence or to submit annual records to the Ministry of Environment. Thus, the use of insecticidal soap (an Excluded pesticide), may in fact be greater than shown because only businesses that were reporting other non-Excluded pesticides would have submitted records showing use of soap. In the past it was unlikely that a landscape service could manage without using at least some reportable pesticides, but this has changed for several reasons:

- Since 1991, the provincial government has had a policy to reduce and eliminate pesticide uses by promoting adoption of integrated pest management (IPM) programs. This is a systematic approach based on prevention. The policy was implemented by sponsoring IPM training, revising the provincial pesticide applicator training materials, and by changes in provincial pesticide legislation to require an IPM approach.
- The new *Integrated Pest Management Act* and Regulation enacted in 2004 included an updated Excluded schedule of pesticides. It now includes a range of recently registered least-toxic pesticides (such as ferric phosphate for slug control and the herbicides based on fatty acids, acetic acid, and corn gluten). This gave landscapers access to a broader suite of least-toxic products to conduct their businesses.
- By the mid-1990s the major B.C. municipalities (notably Vancouver, Victoria, Burnaby, Coquitlam, North Vancouver) began to implement IPM programs and reduce pesticide use; some municipalities adopted policies to use only pesticides listed on the provincial Excluded (Exempted) Schedule.
- Many municipalities in Canada, including large cities such as Vancouver, have restricted pesticide use on private land through municipal bylaws. The bylaws restrict what an individual as well as professional services can use to a list of generally low-toxicity pesticides.

As more companies learn to manage pests with the least-toxic products on the Excluded list, and the list continues to expand as new low-toxicity products are registered in Canada, fewer companies will require licensing to use pesticides.

PHASING OUT TOXIC HOME AND GARDEN PESTICIDES

The following active ingredients previously registered for use in and around homes (i.e., for indoor pests, in flea collars) or residential landscapes and turf have been phased out or discontinued in recent years:

- Atrazine: residential and other uses (except in corn) expired 2006.
- Benomyl: all uses discontinued; last product expired 2004.
- Chlorpyrifos: last sale to retail 2001.
- Diazinon: all domestic and residential use on lawns phased out by 2003.
- Dimethoate: all domestic registered products expired 2004.
- Endosulfan: registrants withdrew all residential uses in 2004.
- Malathion: registrants discontinued turf and indoor uses; only labelled for mosquito control after 2003.
- Methoxychlor: all uses discontinued, last product expired 2005.
- Naled: pet collar uses expired 2003; turf uses expired 2004.
- Paraquat: all domestic, turf uses discontinued; last product expired 2005.
- Pirimicarb: all uses discontinued; last domestic products expire 2007.
- Sodium fluosilicate: all uses expired 2005.

Source: Pest Management Regulatory Agency Re-evaluation Summary Table: *www.pmra-arla.gc.ca/english/pdf/re-eval/summarytable-e.pdf* (updated May 2007).

Supplementary Information: Trends in Sales of Pesticide of Most Concern in the Georgia Basin

The 2003 provincial pesticide study (EC and BCMOE 2005) included an analysis of trends in reportable pesticide sales in the Georgia Basin. This study looked at 40 active ingredients that were included on lists of chemicals of concern by one or more of the following initiatives:

- The 1998 Nominating List of Toxic Substances in the Lower Fraser/Georgia Basin, developed under the Georgia Basin Ecosystem Initiative. It lists 44 substances, 13 of which were pesticide active ingredients (or groups of ingredients), with an emphasis on suspected endocrine-disrupting chemicals.

- A US National Oceanic and Atmospheric Administration list of contaminants of concern in the Puget Sound, developed for the Puget Sound/Georgia Basin Toxics Work Group. This list contains 48 pesticides, 26 of which were sold in Canada.
- A list of contaminants prepared by S.C.H. Grant and P.S. Ross of Fisheries and Oceans Canada (cited in Verrin et al. 2004) that could pose a health risk to southern resident killer whales. The list included 16 pesticide active ingredients that may persist in the environment and bioaccumulate.

In 2003, sales of these pesticides amounted to 95,446 kg, or 17.8% of all pesticides sold in the Georgia Basin that year. Eight pesticides appeared on two or more of the lists: atrazine, simazine, chlorpyrifos, malathion, metalachlor, endosulfan, trifluralin, and lindane. Together, they amounted to 5.7% (30,478 kg) of all pesticides sold in the Georgia Basin.

Table 10 shows the active ingredients registered for landscape uses that appeared on two or more lists of concern. Over the 12 years spanned by the provincial pesticide studies, use of chlorpyrifos (withdrawn in 2001), endosulfan, lindane, and trifluralin decreased to zero. Since then, uses of three landscape pesticides have been withdrawn: residential uses of endosulfan in 2004; turf uses of malathion by 2003; and all uses of lindane in 2006.

Table 10. Quantities of active ingredients on two or more lists of environmental concern used by landscape services in the lower mainland region of B.C., 1991–2003.

	Total used (kg)				
Active ingredient	1991	1995	1999	2003	Change from 1991 (kg)
Chlorpyrifos	15.4	20.0	16.3	0	-15.4
Endosulfan	8.0	3.3	0	0	-8.0
Lindane (gamma-BHC)	0.8	0.4	0	0	-0.8
Malathion	34.0	17.4	0	22.4	-11.6
Simazine	59.1	93.6	76.7	73.7	14.6
Trifluralin	3.5	0.4	0	0	-3.5

Source: Survey of Pesticide Use in BC: 2003 (EC and BCMOE 2005).

WHAT IS HAPPENING IN THE ENVIRONMENT?

A wide range of contaminants originating from a variety of human activities is detectable in the wider environment and in the tissues of wildlife and of people (c.f., Environmental Defence 2005). The indicators in this paper cover the impacts of contaminants and, for most of them, progress in controlling their release in the environment.

Key contaminants described in the indicators include the legacy POPs, PCBs, dioxins and furans, and DDE, all of which are persistent and bioaccumulative, and some organophosphorus pesticides, which are less persistent. Overall, the environmental concentrations of the legacy POPs have fallen as a direct result of regulatory controls instituted in the 1970s–1990s on release of these substances to the environment. Except at contaminated sites, the concentrations found in the air, water, and external environment are generally low. Through bioaccumulation and biomagnification, however, much higher concentrations of these persistent chemicals appear in the blood and tissue of animals near the top of the food chain, as shown in data from herons, cormorants, osprey, seals, and killer whales. Even though it has been 30 years since release of PCBs was prohibited in North America, PCB residues are still the most toxicologically significant of all POPs for animals at the top of the marine food chain. The decline in PCB concentrations in killer whales has been so slow that recent modelling suggests that it could be 60 years before residues decline enough to stop posing a health risk for southern resident killer whales (Hickie et al. 2007).

Adding to the tissue burden from the legacy POPs, are the PBDEs, which have been accumulating in the food chain since the 1970s, but have been only recently recognized as a concern. Environmental contamination with this new class of persistent contaminants has been rising rapidly. PBDE concentrations in the breast milk of Vancouver area mothers doubled every two and half years throughout the 1990s (Ryan et al. 2002). Concentrations have been doubling in marine mammals about every 5 years (Hites 2004) and in marine birds about every 5.7 years (Elliott et al. 2005). Although pentaBDE and octaBDE have been withdrawn from the market, decaBDE is still in use. It is distributed in commercial and consumer products to a greater extent than PCBs were, and there is evidence that it can break down into the more toxic penta- and octaBDE forms (research reviewed in Environment Canada 2006a). This means that residues will likely continue to increase for some time before controls on these substances bring about a decline.

Efforts to eliminate sources of risk from contaminants include: withdrawal of pesticide registrations, elimination of target industrial chemicals from use, cleanup of contaminated sites, and regulatory limits on food residues and exposure in the workplace or from consumer and industrial products. Despite regulations and voluntary controls, however, there are still sources of continuing input of these targeted industrial contaminants to the Canadian environment from the following sources:

- Release of decaBDEs from furniture, textiles, plastics, and other consumer goods.
- Local, industrial, and other activities that deposit small amounts of contaminants, such as dioxins and furans, in the local environment. Common examples are burning salt-laden wood waste, trash in backyard burn barrels, and open burning of wood waste (see "What You Can Do," below).
- Breakdown processes in soils and sediments that are still releasing contaminants from past uses (such as DDE from past use of DDT).
- Accidental releases or spills. In the case of PCBs, there remains a risk that they may be released from controlled storage and landfill sites and from electrical equipment still in use.
- Transport of a variety of contaminants over long distances in the atmosphere from parts of the world where they are still in common use.

In addition to the POPs that were the subject of several of the indicators in this paper, other prominent contaminants, such as mercury, lead, and other heavy metals, were not covered. These have been, and continue to be, the target of long-running regulatory efforts to reduce their impacts on the environment and human health. Because there are often many possible sources for POPs and other contaminants, it is a challenge to make the links between the source and the effects to evaluate the success of mitigation efforts.

Other Contaminant Issues

Two major, emerging contaminant issues not addressed by indicators in this paper are: impacts of exposure to mixtures of contaminants and the release of reactive nitrogen into the global environment from human activity.

- In addition to the residues from earlier use of POPs, which will continue to persist in the global environment for decades, thousands of other substances are currently in use. In the course of daily living, people are exposed to a combination of chemicals (usually at extremely low levels) from many sources. These include widely used chemicals, such as phthalates and biphenol-A (in plastics) and human pharmaceuticals (in drinking water). Unlike drug interactions that have been well tested, the health effects of exposure to mixtures of contaminants are largely unknown. It would be impossible to test all possible combinations of substances, but researchers have begun to examine the effect of some mixtures. Studies on exposure to a combination of endocrine disrupting chemicals (present in plasticizers, sunscreen ingredients, cooling and insulating fluids) found that the resulting impact was additive. Although doses of each chemical were below the '"no effect levels," together their impact was the same as if the doses had been added together. This was shown both for chemicals that block activity of female hormones (e.g., Silva et al. 2002; Brian et al. 2007) and those that block activity of male hormones (e.g., Gray et al. 2006). Although it is not surprising that results were additive for chemicals that target the same pathways, it was surprising that mixtures of unrelated chemicals also produced additive effects (Gray et al. 2006).
- The impact of the reactive nitrogen (e.g., nitrates, ammonia and nitrogen oxides) that has been released into the global environment from human activity has been recognized as an international concern since the First International Nitrogen conference in 1998 (Erisman 2004). Today it is estimated that 70% of reactive nitrogen in the global environment comes from nitrogen fertilizer use and fossil fuel burning (reviewed in Hooper 2006). With effects that include acid rain, air and water pollution, climate warming, and eutrophication, reactive nitrogen has many and extremely complex effects.

When wider-scale monitoring data are available, indicators for emerging contaminants will likely be developed for future reporting. For example, concern about risks to health have driven recent interest in testing for contaminants in human tissue and blood. Statistics Canada is, for the first time, in the process of testing the blood of 5,000 Canadians as part of a comprehensive health survey to be completed in 2009; data from this study could be useful as a baseline for future indicator reporting.

WHAT IS BEING DONE ABOUT ENVIRONMENTAL CONTAMINANTS?

Government Initiatives

Internationally, Canada was the first country to ratify the Stockholm Convention on Persistent Organic Pollutants, in 2001. This international agreement calls for the elimination of: PCBs, dioxin and furans, hexachlorobenzene, and the pesticides DDT, dieldrin, aldrin, endrin, chlordane, heptachlor, toxaphene, and mirex. In 2000, Canada established the Canada Persistent Organic Pollutants Fund with a commitment of $20 million to help developing countries and those with economies in transition deal with POPs. For updates on National Implementation Plans for Canada's obligations under the Stockholm Convention, see *www.ec.gc.ca/cleanairairpur/CAOL/POPS/Stockholm/sum_e.html.*

In Canada, the *Canadian Environmental Protection Act* (CEPA) includes procedures for investigating and assessing substances, and for regulating substances that are, or might become, toxic as defined by CEPA. CEPA required the Minister of the Environment and the Minister of Health to "categorize" all of the approximately 23,000 substances on the Domestic Substances List (DSL) to identify those substances with the greatest potential for exposure or that are persistent or bioaccumulative and inherently toxic to humans and other living organisms. This led to the creation of two Priority Substances Lists, comprising a total of 69 substances or groups of substances. Under CEPA provisions, these were assessed to determine if they are toxic and whether there should be controls over production and release to the environment. A CEPA Environmental Registry provides information to the public and supports public participation in environmental decisions (*www.ec.gc.ca/CEPARegistry/*). The Registry provides access to toxic chemical assessments, inventories of substances and their toxicity, the industries they are associated with, and proposed management strategies and regulations.

At the provincial level, an updated B.C. *Environmental Management Act* (2003) introduced new provisions for toxic substances and waste management, including changes affecting contaminated sites, hazardous wastes, and waste discharge regulations. New sediment criteria incorporated in the Contaminated Sites Regulation provide a strong inducement for industry to avoid creating future contaminated sites. The Act covers a broad range of environmental regulations (see *www.qp.gov.bc.ca/statreg/stat/E/03053_00.htm*).

Under the Canada-wide Environmental Standards Sub-agreement between federal and provincial environment ministers, coastal pulp and paper mills were required to reduce their atmospheric emission of dioxins and furans from burning wood waste to less than 500 pg TEQ/m^3 by 2006 (CCME 2001).

The Canadian Health Measures Survey is a comprehensive health survey by Statistics Canada. It will test blood and urine samples of Canadians ages 6 to 79 to measure many aspects of disease and nutrition as well as environmental exposure to contaminants. The survey will be completed in 2009 and will give federal health officials a baseline on contaminant exposure along with the other results on the health of Canadians. For more information, see *www.statcan.ca/english/concepts/hs/measures.htm.*

WHAT CAN YOU DO?

Around the Home

Avoid releasing hazardous products to the environment:

- Use water-based, low-emission paints, paint removers, stains and varnishes, waxes, glues and adhesives, cleaners, etc. Use cleaning products with natural ingredients.
- Reduce and eliminate the use of toxic pesticides, paints and solvents, carpet and furniture cleaners, glues, and other household hazardous products around the home. If you must use hazardous products buy only enough to do the job to avoid having to store or dispose of them.
- Store hazardous products in their original, tightly closed containers in a well-ventilated area where children and pets cannot get at them. Never burn any household hazardous products in fireplaces or backyard fires.
- Dispose of waste in special household hazardous waste depots. More than 30 free dropoff locations for solvents, pesticides, and gasoline are operated in B.C. by Product Care. For information on acceptable products or to find a dropoff depot near you see: *www.productcare.org* or call the RCBC Recycling Hotline. Established in 1990, the RCBC Recycling Hotline (*www.rcbc.bc.ca/*) is a free, province-wide information service for recycling, pollution prevention, waste avoidance, disposal options, and regulations. In B.C. call toll-free: 1-800-667-4321; in the Lower Mainland call 604-732-9253; e-mail: *rcbc@rcbc.bc.ca*.

Several other disposal programs keep contaminants out of landfills and the environment:

- Batteries: Don't put used batteries from flashlights, clocks, toys, etc. in the garbage. There is a recycling program in B.C. for rechargeable batteries; for a dropoff location near you, see the Rechargeable Battery Recycling Corporation (*www.rbrc.org*) or call the RCBC Recycling Hotline. For alkaline (disposable) batteries there are some local and municipal programs; phone the RCBC Recycling Hotline for local disposal options.
- Motor oil, used oil filters: The B.C. oil recycling program is currently managed by the BC Used Oil Management Association. For your nearest dropoff location see *www.usedoilrecycling.com* or call the RCBC Recycling Hotline.
- Prescription medicines: Never flush away leftover medicines or over-the-counter drugs. Nearly all pharmacies in B.C. participate in the Medications Return Program to collect expired or unused medications for safe disposal. To find a drop-off location see the Residuals Management Association website (*www.medicationsreturn.ca*) or call the RCBC Recycling Hotline.
- Electronics: B.C.'s Return-It Electronics is a province-wide program available to all consumers and businesses in British Columbia. As of August 2007, you can drop off televisions, computers, printers, keyboards, and other products at designated collection sites without charge for proper recycling. For information visit the Encorp website: *www.encorp.ca/electronics/* or contact the RCBC Recycling Hotline.

Build a healthy house: Canada Mortgage and Housing Corporation (CMHC) provides free booklets and brochures and a low-priced book on building healthy homes and retrofitting existing homes to protect occupants from exposure to contaminants. See *www.cmhc.ca* or phone 1-800-668-2642. For healthy home publications click on "Order Desk" and follow links to "Your Health and Your Home."

Around the Yard

Avoid using pesticides (including insecticides, herbicides, fungicides, and other chemicals).

- Learn how to prevent pest problems and manage weeds without using pesticides. For information on Integrated Pest Management in B.C., see *www.env.gov.bc.ca/epd/epdpa/ipmp/* or local municipal websites, many of which have information on sustainable landscapes and gardens.
- For help with identification and advice on how to manage pests without toxic pesticides, consult Master Gardeners at clinics at your local garden centre and local gardening experts.
- Stop burning trash or yard waste. The US Environmental Protection Agency (EPA) found that the largest source of dioxin and furan emissions in the United States is now the burning of household trash (backyard burning). This source accounts for 10 times more emissions than the next highest sources, which are residential wood burning stoves and coal-fired utilities (FNB and IOM 2003). The health risk for people is from exposure through local food as the dioxins settle on plants, which are then eaten by meat and dairy animals. This source of contaminants would be eliminated by halting the practice of burning waste in open piles, burn barrels, or inefficient wood stoves. Many municipalities ban open burning as part of local smoke control regulations. Things you can do instead:
- Have waste picked up by a licensed waste removal company or take it to a local landfill or transfer station.
- Separate recyclables and drop them off at a local recycling centre. For information on recycling or disposal options, call the BC Recycling Hotline at 1-800-667-4321.
- Compost yard and garden waste, food, and leaves. Rent a chipper or hire a service to chip brush and wood to make mulch.
- For more information on avoiding backyard burning, see: *www.env.gov.bc.ca/air/*.

Find out More

- Environment Canada's What You Can Do website (*www.ec.gc.ca/eco/main_e.htm*) provides information on steps individuals can take to protect the environment. For suggestions for reducing your exposure to hazardous chemicals and ways to reduce the use of household hazardous waste and dispose of it safely, see *www.ec.gc.ca/eco/wycd/home6_e.html*.

- The Canadian Pollution Prevention Information Clearinghouse (CPPIC) is a searchable database of references and links to give Canadians access to information on pollution prevention, (*www.ec.gc.ca/cppic/en/index.cfm*).
- Greenpeace has been rating electronics companies according to their environmental record since 2005. They rate contaminants used in computers, cell phones and other equipment as well as manufacturing and disposal provisions. See Guide to Greener Electronics: *www.greenpeace.org/electronics/*.
- David Suzuki Foundation (*www.davidsuzuki.org*). Information on many aspects of environmental protection. For specific information on contaminants and human health see the 2007 report: Prescription for a Healthy Canada *www.davidsuzuki.org/Publications/Prescription_For_A_Healthy_Canada.asp*.

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Ecosystems

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Ecosystems

BACKGROUND

An ecosystem is a complex, interlinked system of living things (plants, animals, fungi and microorganisms) and their physical environment (e.g., soil, air, water). From the depths of the Pacific Ocean to the peaks of the Rocky Mountains, British Columbia has a multitude of ecosystems, from seafloor, kelp beds, shorelines, estuaries, forests, grasslands, wetlands, lakes and rivers, to mountain slopes and alpine meadows. This ecosystem diversity is the result of complex geography and varied climate, and is why B.C. is home to more species than any other Canadian province (Cannings and Cannings 1996).

Ecosystems include thousands of plant and animal species. Habitat is that part of an ecosystem that a particular species depends on for its life requirements, such as food, shelter, and nesting sites. A dead tree in a forest ecosystem is both a feeding and nesting habitat for a pileated woodpecker. A seasonal pond in a grassland ecosystem is the breeding habitat for Great Basin spadefoot toads.

In addition to providing habitat for animals, ecosystems also provide many 'services' on which humans rely: food production, water purification, waste treatment, oxygen production, climate regulation, flood protection, erosion control, and many others (MEA 2005). These ecological services are critical for the survival of all organisms, including humans, and they underpin human economies and social and cultural systems. Costanza et al. (1997) estimated that, on average, Earth's ecosystems provide services worth US$33 trillion each year.

Some animal species live mainly in one type of ecosystem (e.g., Vancouver Island marmots live only in subalpine meadows). Wide-ranging animals, however, such as grizzly bears, use many ecosystems. Grizzlies range over many square kilometres from valley bottoms to mountain tops. Animals may use different ecosystems for different parts of their life cycles. Marbled murrelets, for example, need old growth coastal forests for nesting habitat but depend on the open ocean ecosystem for the rest of their life cycle. This means that what happens in one ecosystem can have wider impacts, affecting the habitat of animals in another ecosystem. For example, discharge of pollutants into the Fraser River affects the habitat of crabs and killer whales living in the Strait of Georgia. Relationships in ecosystems are extremely complex and not well understood.

Human activities in the province, especially in the past century and a half since European settlement, have modified, degraded, and even eliminated ecosystems in B.C. Logging, agriculture, urban and industrial development, the release of contaminants into the air and water and changing climate are all affecting the natural landscape. Examples of ecosystems in B.C. most at risk from these activities include grasslands, antelope brush steppe, old growth forests, Garry oak meadows, wetlands, estuaries, and salmon streams (BCMELP and BCMOF 1999). Humans are also trying to reduce the impact of these activities by conserving and protecting ecosystems in British Columbia. Some ways to protect ecosystems include establishing parks and other protected areas, creating environmental legislation and policies to guide development activities, and educating people about stewardship of ecosystems.

Ecosystems are complex, with many interrelated components. The Millennium Ecosystem Assessment (MEA 2005), which reported on the vast human-made changes to global ecosystems in the past 50 years, identified lack of knowledge as a major constraint on effective ecosystem management. Similarly, in B.C., lack of information about the province's ecosystems often hinders the ability to monitor and assess their condition.

The ecosystem indicators reported in this paper use information that is currently available on a provincial scale or from regional or local studies. The indicators show the status of some important B.C. ecosystems (grasslands, forests, streams, and estuaries), the progress that has been made in protecting them (amount and effectiveness of protected areas), and the pressure on ecosystems from road building (length and intensities of roads in B.C.) and other human activities (intertidal tenures).

INDICATORS

1. Key Indicator: Status of grassland habitats in southern interior B.C.

This is a status or condition indicator, showing the current distribution of the grassland ecosystems in British Columbia. It answers the questions: How much of the province's historical grasslands have been lost and what areas remain intact?

Grasslands are open areas where grasses or grass-like plants are the dominant vegetation. Grasses thrive in hot, dry climates most often associated with the sheltered side of mountainous terrain, away from prevailing winds and where spring and summer rains are sparse. At one time, grasslands extended over a wide area of the province. After the glaciers retreated at the end of the last Ice Age (about 9,000 years ago), the climate became warmer and drier and the barren landscape was colonized by grasses, sedges, and shrubs. During a later cool period 4,500 to 3,000 years ago, forests expanded over most of the province. Figure 1 shows the current distribution of grasslands in the province.

For thousands of years, First Nations in the interior of the province relied on grasslands for subsistence as well as for medicines and other purposes. They altered the landscape by cultivating native plants, irrigating bean and corn crops, and using fire to improve forage for deer and elk (Blackstock and McAllister 2004) and to enhance native berry and root crops. However, it was not until European settlement in the mid-1800s that agriculture and ranching began to change grassland ecosystems on a much larger scale. Since then, many activities have contributed to the loss, fragmentation, and degradation of grasslands: intensive agriculture, livestock grazing, urbanization, hydroelectric dams (reservoirs), off-road recreation, fire suppression, forest encroachment, and the introduction of alien plant species (GCCBC 2004).

Figure 1. Location of grasslands in British Columbia.

Source: Grasslands Conservation Council of BC 2007.

B.C.'s grasslands are one of Canada's most endangered ecosystems. More than 30% of the province's species at risk (e.g., badger, burrowing owl, pallid bat, Great Basin gopher snake, western rattlesnake, long-billed curlew) live in southern interior grassland habitats (GCCBC 2007). Other habitats associated with open grasslands, such as rocky slopes and outcrops, riparian areas, wetlands, ponds, lakes, gullies, and parklands, support a diversity of species.

This grassland status indicator focuses on the southern interior where most of B.C.'s grasslands occur: the Cariboo-Chilcotin, Thompson-Nicola, Okanagan, and East Kootenay regions. The Peace River region in northeastern B.C. once included extensive grasslands interspersed with aspen and willow. However, agricultural development over the past century has left only remnants of grassland on the steep, south-facing slopes of larger river valleys. Grasslands also occur on the drier plateaus and slopes of the subalpine and alpine areas of the province. On the coast, the native grasslands are associated with Garry oak woodlands. These now consist of pockets of meadow on southern Vancouver Island and the Gulf Islands. (See text box "Loss of Garry oak habitat on Vancouver Island.")

Methodology and Data

Data for this analysis of the lost area of southern interior grasslands are from the following sources:

- The final report of the Grassland Conservation Council of British Columbia (GCCBC): B.C. Grasslands Mapping Project: A Conservation Risk Assessment, was completed in May 2004. The project used provincial data inventories created between 1990 and 1995. It is the source of data on grassland loss from the mid-1800s to the 1990–1995 period. Early extent of grasslands were determined from a variety of sources, including historical photos, site specific information from experts, soil maps delineating grassland soil types, and early aerial photography (from 1938 onward). More information on methods is available at *www.bcgrasslands.org/projects/conservation/mapping.htm.*

- An updated analysis by the GCCBC in 2007, using digital aerial photography from 1990 and 2005, was commissioned by the B.C. Ministry of Environment.
- Data in this indicator were analyzed at the ecosection level of the Ecoregion Classification System of British Columbia (Demarchi 1996). An exception is the area referred to as "Cariboo-Chilcotin," which is a grouping of four ecosections (Fraser River Basin, Cariboo Basin, Chilcotin Plateau, and Central Chilcotin Ranges). No data were available for the Northern Okanagan Highland ecosection and it was therefore omitted from this analysis. The term "southern interior" is used in a general geographic sense; it does not refer to the Southern Interior Ecoprovince as used in the Ecoregion Classification System of British Columbia.

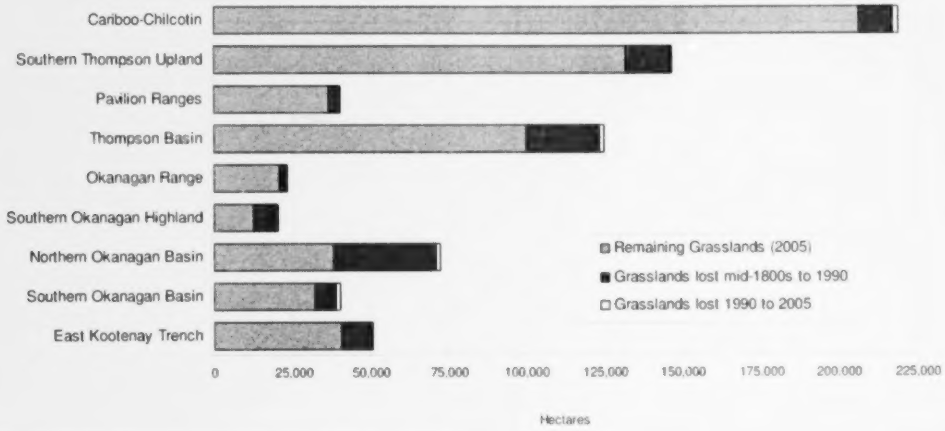
The analysis for the 2004 grasslands mapping report (GCCBC 2004) was based primarily on forest cover inventory maintained by the B.C. Ministry of Forests. To increase the accuracy and consistency of the grasslands assessment, units of grassland were checked using aerial photography, orthophoto mosaics, Landsat imagery, and detailed provincial ecosystem inventories (e.g., Terrestrial Ecosystem Mapping, Predictive Ecosystem Mapping, Sensitive Ecosystems Inventory; more information on these inventories is available at *www.env.gov.bc.ca/ecology/index.html*).

The GCCBC's updated analysis in 2007 identified the areas of grasslands lost to development between 1990 and 2005. ArcMap GIS software was used to identify grassland development on digital orthophoto images from 1995 and 2005. If developed areas were visible only on the new image (2005) they were given an age of 10 years; if they occurred on the old image (1995) they were aged at 15+ years. Rates of grassland development were then assessed with a GIS analysis of GCCBC grasslands maps using the provincial Broad Ecosystem Inventory and Biogeoclimatic Ecosystem Classifications. The data are presented by ecosection but the areas and percentages in the following tables refer to the grassland portion of an ecosection only.

For the 2004 GCCBC report, grassland development types were classified as either "agriculture" or "urban." In the 2007 update there were four development types:

- Agriculture: includes irrigated hayfields, vineyards, orchards, and ginseng.
- Urban/industrial: includes higher density urban or industrial development.
- Acreages: includes groups of low-density developments or single acreage homes.
- Other: includes aggregate and open pit mines, golf courses, recreation (off-road vehicle disturbances, Merritt Mountain music festival), logged areas (forest patches within grasslands), and highway expansion.

Figure 2. Loss of grasslands in southern interior B.C. before 1990 and between 1990 and 2005, by ecosection.



Data source: Grasslands Conservation Council of BC 2004, 2007.
Note: All ecosections had some grassland loss between 1990 and 2005, but those with less than 2% are not shown on this graph.

Interpretation

The analysis found that 16% of B.C. southern interior grasslands has been lost to development since the beginning of European settlement in the mid-1800s (Figure 2, Table 1).

- About 15% of southern interior grasslands (111,385 ha) were lost to development between the mid-1800s and 1990. Of this, about 11% was lost to agriculture and 4% to urbanization.
- Another 1% (7,657 ha) of grassland was lost in the 15 years between 1990 and 2005. Of these recent losses, 37% was to agriculture, 30% to urbanization, 23% to acreages, and 10% to other types of development.
- The Northern Okanagan Basin ecosection had the most development, losing almost half (48%) of its grasslands by 1990.
- More than one-third (39%) of the grasslands in the Southern Okanagan Highland ecosection were also lost by 1990. Other ecosections with high losses by 1990 include the Thompson Basin, the South Okanagan Basin, the Southern Thompson Upland, the East Kootenay Trench, and the Cariboo-Chilcotin ecosections.
- Between 1990 and 2005, another 4% of the Northern Okanagan Basin and Southern Okanagan Basin grasslands and about 2% of the Cariboo Basin and Thompson Basin grasslands were lost.
- At a finer scale, in the Okanagan's lower elevation bunchgrass zone (Vernon to Osoyoos), the losses are greater: 40–70% of shrub steppe and bluebunch wheatgrass habitats are gone; in associated habitats, almost 40% of cattail marshes and 60–90% of riparian habitat types have been lost (Lea 2007).

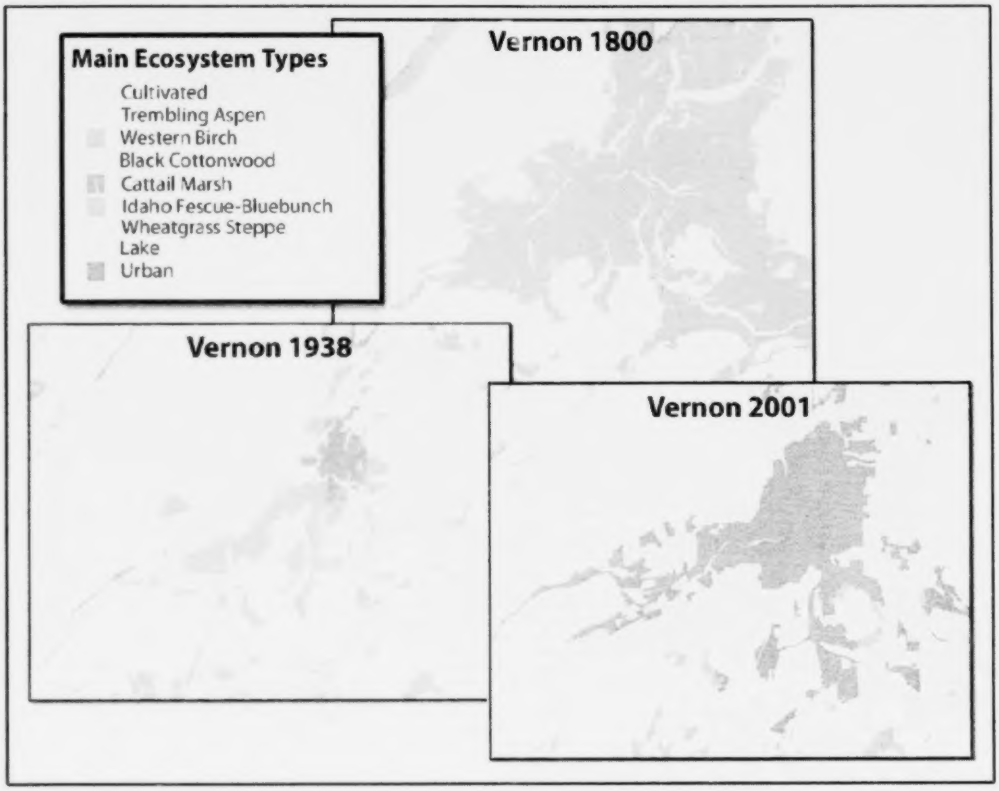
Table 1. Grasslands lost in the southern interior of B.C. from the mid-1800s to 2005.

Ecosection	Historical extent of grasslands (ha)	Grasslands lost mid-1800s to 2005 (ha)	Historical grasslands lost mid-1800s to 2005	Grasslands remaining in 2005 (ha)
Northern Okanagan Basin	72,680	34,620	47.6%	38,060
Southern Okanagan Highland	20,340	7,844	38.6%	12,496
Southern Okanagan Basin	40,330	8,281	20.5%	32,049
Thompson Basin	125,240	25,018	20.0%	100,222
East Kootenay Trench	50,590	9,964	19.7%	40,626
Okanagan Range	23,270	2,606	11.2%	20,664
Southern Thompson Upland	146,970	14,672	10.0%	132,298
Pavilion Ranges	40,190	3,505	8.7%	36,685
Cariboo-Chilcotin ecosections	219,305	12,529	5.7%	206,776
Totals	738,915	119,041	16.1%	619,874

Data source: Grasslands Conservation Council of BC 2004.

A recent historical ecosystem mapping project for the Vernon area shows the extent of these losses since the 1800s (Figure 3). The low-elevation grassland and shrub-steppe ecosystems are particularly significant to many plant and animal species at risk.

Figure 3. Historical extent of five important grassland habitats in Vernon, B.C., during three time periods (1800, 1938, and 2001), and extent of lakes, cultivated and urban areas.


Main Ecosystem Types
Cultivated
Trembling Aspen
Western Birch
Black Cottonwood
Cattail Marsh
Idaho Fescue-Bluebunch Wheatgrass Steppe
Lake
Urban
Vernon 1800
Vernon 1938
Vernon 2001

Source: Lea (2007).

Grasslands occur in hot, dry climates where grasses are the dominant vegetation. In such areas, water is a limiting resource for human settlement, so it is not surprising that most of the development on southern interior grasslands occurs along rivers and lakes in the valley bottoms. Agricultural fields, vineyards, and orchards are mainly near major water sources in the Fraser, Thompson, Okanagan, and Kootenay river basins. People have also settled along these water courses at low elevation, creating urban, industrial, and residential centres such as Kamloops, Kelowna, and Cranbrook. In the process, grassland has been lost, fragmented, or degraded due to development. Unfortunately, valley bottoms are also critical habitats for many wildlife species. Due to population growth in the last few decades there is an increasing demand for urban and residential development, which is now encroaching on the remaining low-elevation grasslands as well as mid- and higher elevation grasslands.

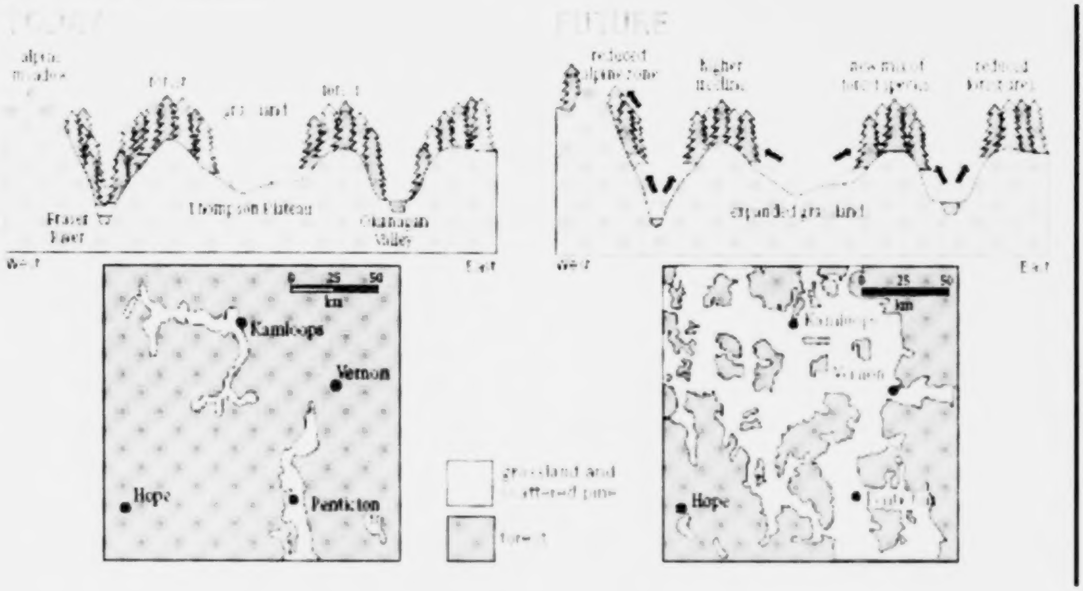
Although 84% of southern interior grasslands remain, this does not mean they are unaffected by human activities. The GCCBC (2004) reported that about 90% of all B.C.'s grasslands are grazed by domestic livestock and that poor land management practices, such as overgrazing, and spread of introduced, invasive plants has degraded many grassland ecosystems. A study of 17 grassland sites in southern interior B.C. revealed that introduced plant species covered an average of 35% of the sites, with some sites having up to 85% coverage of non-native species (Gayton 2004). Increasing pressure from recreational activities, such as disturbances from off-road vehicles and conversion to golf courses, also threaten grasslands (GCCBC 2004).

Supplementary Information: Impact of climate change on grasslands

The increasing temperatures, and the projected drier summers, in the interior of the province as a result of climate change are expected to alter grassland and dry interior forest ecosystems. Within another 75 years, B.C.'s grasslands are projected to expand northward and into higher elevations (Figure 4), replacing adjacent dry forests. This is likely to be particularly evident in the southern Rocky Mountain Trench and south Chilcotin areas (Hebda 2007). In the Okanagan, much of the current ponderosa pine forests may be replaced by bunchgrass ecosystems (Nitschke 2007). As a result, there may be more habitat for grassland wildlife species. Species that rely on the other types of habitats associated with grasslands, such as wetlands and forest patches, are particularly vulnerable to climate change.

The composition of the plant communities in future grasslands is likely to be different from that of current or past grasslands as introduced invasive species outcompete native species. Preservation and restoration of existing grasslands is increasingly important to ensure there is an ecologically healthy foundation for future grassland ecosystems.

Figure 4. Predicted effects of climate change on distribution of B.C.'s southern interior grasslands and forests.


FUTURE
alpine meadow
forest
grassland
forest
Fraser River
Thompson Plateau
Okanagan Valley
West
East
reduced alpine zone
higher treeline
new mix of forest species
reduced forest area
expanded grassland
West
East
0 25 50
km
Kamloops
Vernon
Hope
Penticton
grassland and scattered pine
forest
0 25 50
km
Kamloops
Vernon
Hope
Penticton

Source: Hebda (2007). Reproduced with permission of the Minister of Public Works and Government Services Canada 2007, and courtesy of Natural Resources Canada, Geological Survey of Canada.

2. Secondary Indicator: Area of protected grasslands in B.C.

This is a response indicator, showing what is being done to protect remaining areas of the province's grassland ecosystems. It answers the question: How much of the province's southern interior grasslands is protected and where are the protected areas?

Methodology and Data

Data sources and methods were the same as those used for Indicator 1. Data were from the final report from the Grassland Conservation Council of British Columbia (GCCBC): BC Grasslands Mapping Project: A Conservation Risk Assessment, completed May 2004. The mapping project used provincial data inventories that were created between 1990 and 1995 to identify the amount of grasslands remaining in the southern interior (Table 1) and subsequently, the amount of protected grasslands in the southern interior (Table 2).

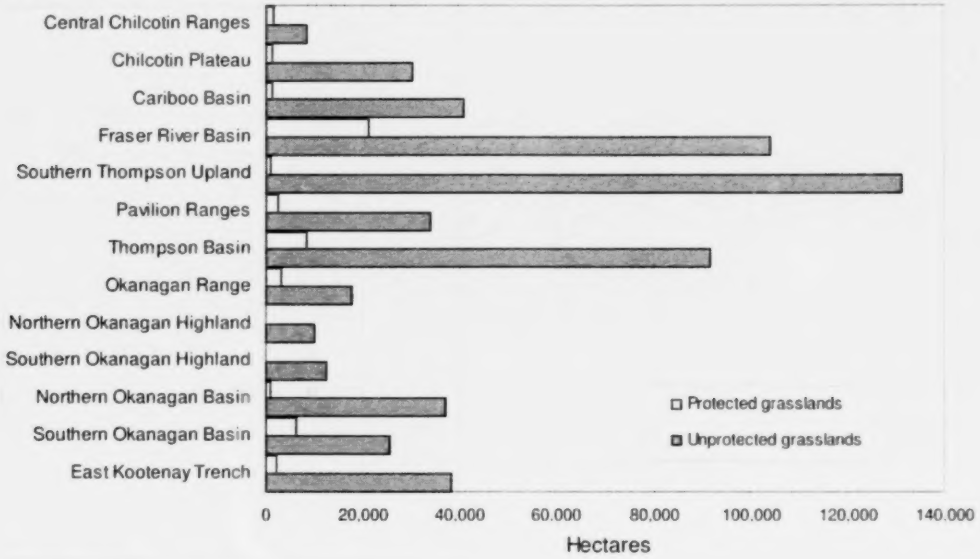
For this analysis, a "protected area" is defined as a provincial park, protected area, wildlife reserve, or ecological reserve. Land acquired or managed for conservation by groups such as The Nature Trust of BC, The Land Conservancy of BC, The Nature Conservancy of Canada, and the Canadian Wildlife Service was also included. The analysis counted only the actual area of grassland within a protected area, which was usually only part of the total area of a park or protected area.

Table 2. Area of protected grasslands, by ecosection, in the southern interior B.C., 2004.

Ecosection	Total grassland (ha)	Total protected (ha)	Percentage protected	Total not protected (ha)	Percentage not protected
Southern Thompson Upland	132,298	961	0.7%	131,337	99.3%
Fraser River Basin	125,265	21,185	16.9%	104,080	83.1%
Thompson Basin	100,222	8,571	8.6%	91,651	91.3%
Cariboo Basin	41,947	1,135	2.7%	40,812	97.3%
East Kootenay Trench	40,626	2,296	5.7%	38,330	94.4%
Northern Okanagan Basin	38,060	1,064	2.8%	36,996	97.3%
Pavilion Ranges	36,685	2,650	7.2%	34,035	92.8%
Southern Okanagan Basin	32,049	6,349	19.8%	25,700	81.0%
Chilcotin Plateau	31,477	1,223	3.9%	30,254	96.1%
Okanagan Range	20,664	3,004	14.5%	17,660	85.5%
Southern Okanagan Highland	12,496	66	0.5%	12,430	99.5%
Northern Okanagan Highland	10,188	267	2.6%	9,921	97.4%
Central Chilcotin Ranges	9,844	1,418	14.4%	8,426	85.6%
Total	631,821	50,189	7.9%	581,632	92.1%

Source: GCCBC (2004).

Figure 5. Area of protected grasslands, by ecosection, in the southern interior of B.C., 2004.



Data source: GCCBC (2004).

Interpretation

The analysis shows that in 2004, about 8% of southern interior grasslands were protected. The ecosections with the highest proportion of protected grasslands were the Southern Okanagan Basin (20%), Fraser Basin (17%), Okanagan Range (14%), and Central Chilcotin Ranges (14%).

About 50,000 ha of grassland are in the provincial parks and protected areas in the southern interior (Figure 5, Table 2)

Some ecosections (e.g., Southern Okanagan Basin and Okanagan Range) have a large proportion of their area protected, while other areas are under-represented in the provincial protected areas system. For example, the Southern Thompson Upland ecosection has the largest area of grassland but the lowest proportion protected. This may be because, unlike the other southern interior grassland areas, this region does not have a completed Land and Resource Management Plan that would designate areas to protect. Another factor may be the high proportion of private lands in this ecosection compared to others (GCCCB 2007).

In the East Kootenay Trench, only 1.3% of grasslands are protected by provincial parks (the largest, Kikomun Creek is only 316 ha), the remaining 4.4% of this ecosection's protected grasslands are properties acquired or managed in partnership with organizations such as The Nature Trust of British Columbia and The Land Conservancy of British Columbia.

The effectiveness of protection depends on the proximity to other protected areas, quality of the environment around the protected area, and the impact of internal and external stressors on the protected area. As shown in Figure 14, there is little remaining ecologically intact area in the southern interior of the province. Most protected grasslands are isolated from each other with little connectivity between them. In addition, activities allowed within protected areas may affect the quality of protection. For example, designation as a provincial park does not necessarily preclude grazing and, in some parks, pre-existing grazing rights were established before the park was created.

Table 3. Provincial parks and protected areas in B.C.'s southern interior with areas of grassland larger than 700 ha.

Ecosections	Provincial parks and protected areas with >700 ha protected grasslands	Area of protected grassland (ha)
Southern Okanagan Basin and Okanagan Ranges	South Okanagan Grasslands Protected Area	5,038
	White Lake Grasslands Protected Area	1,230
	Snowy Protected Area	738
Thompson Basin-Pavilion	Lac du Bois Grasslands Prov. Park	7,076
	Edge Hills Prov. Park	1,706
	Elephant Hill Prov. Park	925
Southern Thompson Upland	Tunkwa Provincial Park	815
Cariboo-Chilcotin ecosections	Churn Creek Protected Area	18,885
	Junction Sheep Range Prov. Park	3,142
	Tsyl-os' Prov. Park	1,187
	Chasm Prov. Park	1,009

Data source: GCCBC (2004).

PROPOSED SOUTH OKANAGAN-SIMILKAMEEN NATIONAL PARK RESERVE

Parks Canada is currently assessing the feasibility of designating a national park in the South Okanagan-Similkameen area. The proposed national park reserve would represent the Interior Dry Plateau Natural Region in Canada's national park system. It would protect much of the Southern Okanagan Highland and Okanagan Range ecosections and would add considerably to the protected area of the Southern Okanagan Basin. More information is available at *www.pc.gc.ca/progs/np-pn/cnpn-cnnp/os-os/index_e.asp*.

3. Secondary Indicator: Status of B.C. forests

This is an impact indicator. It addresses the question: How much have the province's forests been altered by human activities?

Two-thirds of the province's 95 million hectares of land is forested. These forests are diverse ecosystems that reflect B.C.'s mountainous terrain and varying climatic zones. The Pacific coast's oceanic environment and steep topography brings mild temperatures and abundant rainfall. East of the Coast Mountains, the interior plateaus experience a dry continental climate. The northeast corner of the province has a continental climate with very cold winters. As a result, B.C. forests range from temperate rainforests to dry pine forests and black spruce muskegs. Forests are also associated with grasslands, parklands, and alpine meadows.

Low-elevation and valley bottom forests are generally more productive for forestry, agriculture, and wildlife habitat. This is where conflicts between human use and wildlife occur most often. Although high-elevation (subalpine) forests have little economic value for forestry, they still have important ecological and wildlife values. For example, more than 200 of the approximately 600 terrestrial vertebrate species associated with forests in B.C. live in high-elevation forests, either year round or for part of the year (Stevens 1995). Some, such as tailed frog, spotted owl, ermine, and wolverine, are species at risk (CDC 2007).

Coastal and interior forests are distinctly different. The mild, wet climate of coastal forests produces larger, older trees than the harsher, drier climate of interior forests. On the coast, old trees may reach heights of 80 m or more, and some red cedar and hemlock trees are more than a thousand years old. The harsh climate and the frequency of wildfires in the interior means trees do not grow as tall or live as long before attaining old growth characteristics.

Before Europeans arrived, First Nations people living in what is now British Columbia, cut trees, planted crops, and cleared small areas of land. They set fires to enhance the growth of food and forage plants, hunt game, and protect their settlements from wildfires (e.g., Turner 1999; Blackstock and McAllister 2004). Natural disturbances, such as wildlife, insect attacks, landslides, erosion, and wind storms, and human-caused disturbances have always been part of the forest ecosystem. However, the scale and rate of forest disturbance increased after European settlement in the mid-1800s. Human-caused disturbances include logging, wildfire suppression, livestock grazing, and prescribed burning.

OLD GROWTH VERSUS OLDER FOREST

It is important to distinguish between the terms "old growth" and "older forest."

An old growth forest is defined by its age and structure. Important attributes of old growth forests include the large, old trees, as well as standing dead trees, fallen dead or decaying trees, and a multilayered canopy with openings that allow light to reach the forest floor (BCMSRM 2003). Such attributes are not part of the Baseline Thematic Mapping system used here, so it is not possible to identify the amount and location of true "old growth" forest.

The term "older forest," defined as forest older than 140 years, is used in this paper and in other forestry analyses. Because forests were relatively undisturbed until the beginning of European settlement 140–150 years ago, forests categorized as "older forest" are considered to have been undisturbed by logging (but they may have been disturbed by fires or other natural events).

Most coastal forests older than 140 years have at least some characteristics of "old growth" forests. It is estimated that about three-quarters of older coastal forests (as classified by the Baseline Thematic Mapping system used in this indicator) are actually more than 250 years old and would be considered true old growth forests.

Trees in the older forest category range from the towering trees typical of old-growth rainforest to the old but stunted trees of the high-elevation krummholz forests near the treeline.

The 2006 report on the State of B.C.'s Forests provides an analysis of the area of older forest by forest type and elevation in both the interior and coast of the province (BCMOFR 2006a).

Methodology and Data

The data for this indicator came from provincial Baseline Thematic Mapping (BTM). BTM incorporates data from satellite images with additional information from 1:20,000 forest inventory maps (where that inventory is available) to distinguish between old and young forest. The BTM data (scale 1:100,000) represent land types as of approximately the mid-1990s (1992–1999), depending on when the satellite images were acquired.

This analysis includes both land cover and land use categories. Land cover is the composition and characteristics of the land surface resulting from a mixture of natural and human influences (Cihlar 2000). Land use is characterized by the economic uses of land and people's relationships with the environment (Avery and Berlin 1992).

To calculate the area of land covers and land uses (Figure 6, Table 4), the 19 land types designated in BTM were grouped into five categories:

1. **Standing forest**: All categories of forests more than 20 years old, including:
    - Older forest – forests more than 140 years old
    - Younger forest – forests 21 to 140 years old
2. **Recently disturbed forest**: Forests that have been selectively logged, clear-cut, or burned in the last 20 years.
3. **Natural non-forest**: Alpine areas, avalanche chutes, barren surfaces, ice, shrub, wetlands such as bogs and fens, and rangeland (natural grasslands, some of which may be used for grazing).
4. **Water**: Lakes, rivers, and the intertidal portion of estuaries.
5. **Human uses**: Urban areas, agricultural and mixed agricultural-urban areas, mines, and recreation sites (primarily rural golf courses and ski hills).

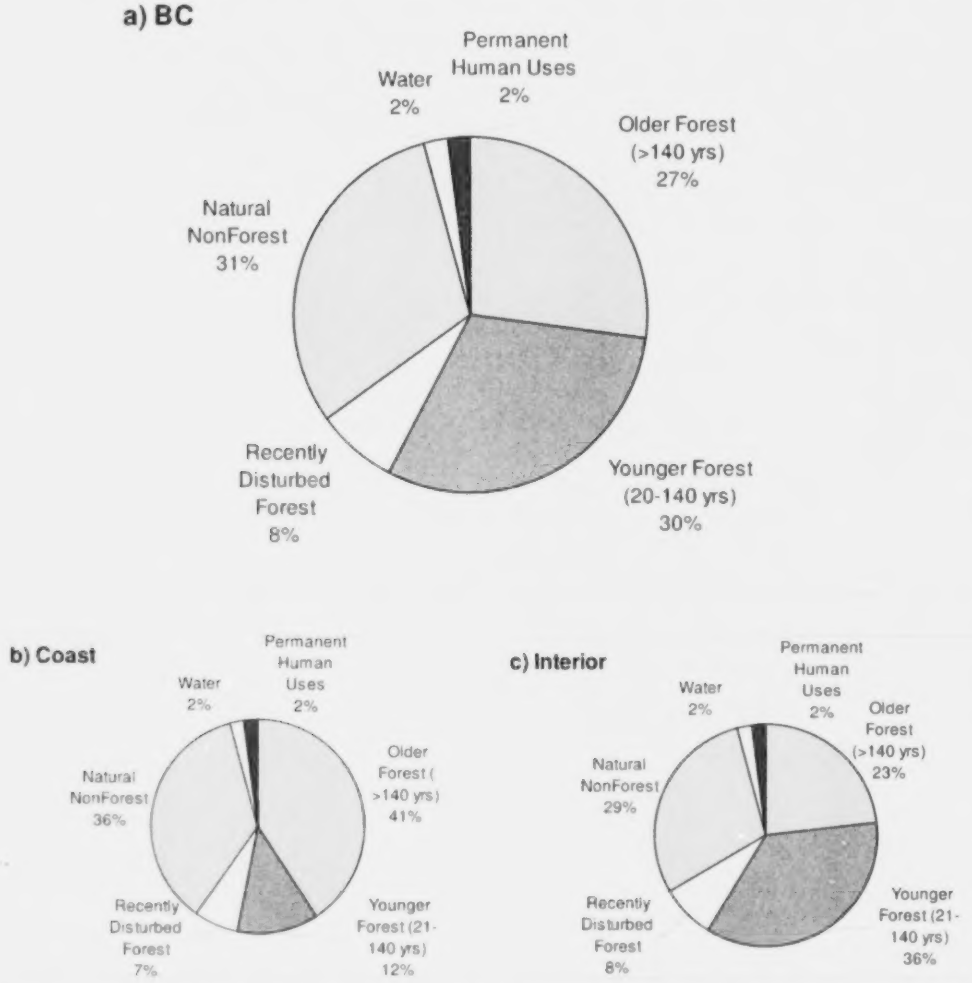
Table 4. Area and percentage of B.C. by land cover or land use (mid-1990s).

Land cover or land use	Area (ha)	% of total
1. Standing forest		
Older forest (≥140 yrs)	25,723,316	
Younger forest (21–140 yrs)	28,691,594	
Total standing forest	54,414,910	57.4
2. Recently disturbed forest		
Recently logged	5,025,474	
Selectively logged	823,851	
Burned	1,410,109	
Total recently disturbed	7,259,434	7.7
3. Natural non-forest		
Alpine	13,084,801	
Avalanche chutes	5,126,723	
Barren surfaces	1,078,456	
Rangeland	798,621	
Shrub	1,602,770	
Wetland	3,961,728	
Ice	3,489,417	
Total non-forest	29,142,517	30.7
4. Water		
Estuary	28,868	
Fresh water (lakes, rivers)	2,162,812	
Total water	2,191,680	2.3
5. Permanent human use		
Urban	368,952	
Agriculture	1,294,849	
Mixed agriculture-urban	61,742	
Mine	60,182	
Recreation	25,821	
Total human use	1,811,547	1.9
Total (all land area of BC)*	94,820,088	100

Source: Integrated Land Management Bureau, B.C. Ministry of Agriculture and Lands (2007).

* Calculations for total land area of B.C. may differ from other indicators in this report because different map scales were used for each analysis.

Figure 6. Proportion of land area in B.C. by land use or land cover (mid-1990s), (a) B.C. total, (b) coast, and (c) interior.



Source: Baseline Thematic Mapping, Integrated Land Management Bureau, B.C. Ministry of Agriculture and Lands (2007).

Note: "Coast" is defined as the Coast and Mountains and Georgia Basin ecoprovinces (Demarchi et al. 1990); "Interior" is the remainder of the province east of the Coast Mountains height of land.

Interpretation

Over the past 150 years, human activities in B.C. have converted some forests to non-forested land and made large-scale changes to other forested areas. By the mid-1990s, of the total land area of the province:

- About 27% was still in older trees (over 140 years old).
- About 30% was forested with trees 21–140 years old, and 8% was recently disturbed forest (logged or burned within the 20 years before the mid-1990s).
- 31% was naturally non-forested (alpine, ice, barren, shrub, grasslands, and wetlands) and just over 2% was water (lakes, rivers, and estuaries).
- Almost 2% (including land that was originally either forested or naturally non-forested land) had been entirely converted to human uses (principally through urbanization and agriculture).

The proportion of land area occupied by human uses, freshwater, natural non-forest, and recently disturbed forest is similar in both the coast and interior areas of the province (Figure 6a). The main differences between the coast and interior forest are in the proportion of older and younger forests. Much of the remaining older forest on the coast is at higher elevations (BCMOFR 2006a) and a large part of the low-elevation old forest—where high biodiversity values occur—is gone.

Although less than 2% of the province's land area has been converted to non-forestry uses, most of this permanent change has occurred at lower elevations, particularly along valley bottoms where most of B.C.'s population lives. This has a large impact on wildlife and biodiversity because the valley bottoms have forest, riparian (streamside), and wetland ecosystems that provide valuable habitat for wildlife. Forestry activities, such as logging and road-building, involve much larger areas of land than urban and rural development activities. Although these activities have less permanent impacts on forests than conversion to other uses, the loss of old growth habitat has a substantial impact on the long-term survival of old-growth–dependent species (invertebrates, lichens, birds, etc.).

Of the province's land area, 38% is currently occupied by forests less than 140 years old. Forestry activity changes older forests to recently disturbed forests that then grow back into younger forests through reforestation (either natural or planted). Natural events such as forest fires have the same effect.

Much of the younger forest area of the province is naturally regenerating after wildfires, especially in the interior where forest fires are more frequent than on the coast. The current mountain pine beetle infestation in the interior is also killing pine trees over large areas. Beetle-damaged trees and salvage logging is increasing the area of recently disturbed forest.

Supplementary Information: Impact of climate change on B.C.'s forests

Climate change will have a profound impact on B.C.'s forest ecosystems. A report by the B.C. Ministry of Forests and Range predicts that warmer temperatures will increase the frequency and severity of fires, storms, floods and droughts, increase the spread of invasive species and affect the health and productivity of forests (BCMOFR 2006b). A predicted increase in insect and disease outbreaks is already being seen with the destructive spread of mountain pine beetle and in the increased incidence of *Dothistroma* needle blight in lodgepole pine forests (e.g., Woods et al. 2005).

From an ecological point of view, climate change is expected to bring about major shifts in the distribution of forests in B.C., including the up-slope movement of the tree line, disappearance of forests in warm, dry areas, northward migration of forest types in the interior, and encroachment into alpine areas (e.g., Hebda 1997). Some species of animals may gain habitat in forest types that are predicted to expand. Fragmentation by roads and agricultural and urban areas, however, may restrict how successfully these species can move from their changing habitat to newly establishing habitat. Other species will lose habitat, such as those at the southern edge of their distribution or that live at higher elevations or occupy specialized habitat (Harding and McCullum 1997).

A study to model potential climate impacts found that tree species with their northern range limit in B.C., such as grand fir, Douglas-fir, and redcedar, may gain habitat at a pace of 100 km per decade (Hamann and Wang 2006). The colonization of individual tree species may not occur as quickly or at all. The gain is in appropriate climate and not necessarily other habitat requirements such as soil type or nutrients. The model showed that common hardwoods such as balsam poplar and red alder may be less sensitive to climate change, whereas important conifer species such as spruce and lodgepole pine could lose a large portion of suitable habitat. The current sub-boreal and montane forest ecosystems are expected to disappear.

The Royal BC Museum provides an interactive display of maps showing forecasts of how the conditions preferred by redcedar, oak, and other species would change in the future as the climate changes (see *www.pacificclimate.org/impacts/rbcmuseum/index.cgi*).

Supplementary Information: Garry oak ecosystems: past, present…future?

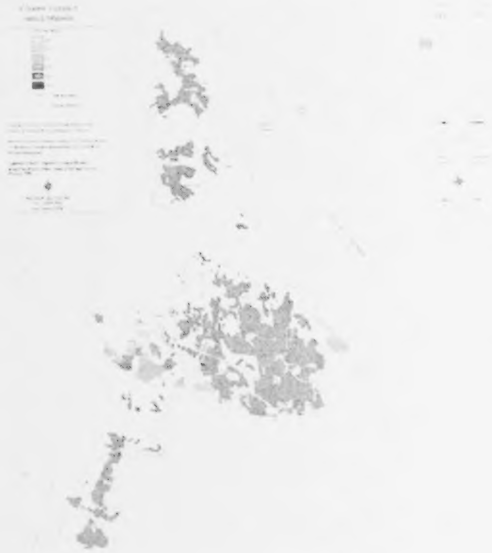
Garry oak ecosystems occur in B.C. only on southeastern Vancouver Island and adjacent Gulf Islands, plus two isolated groves east of Vancouver. The Garry oak landscape was a mosaic of woodlands, grasslands, vernal pools, scattered Douglas-fir stands, and open rocky areas. It is one of the most diverse terrestrial ecosystems in the province, containing many species at risk of extinction.

Rare plants such as Howell's triteleia, golden paintbrush, and deltoid balsamroot and many invertebrates, such as robber flies, butterflies, and seed bugs, are restricted to these sunny, coastal meadows. The vulnerable propertius dusky-wing butterfly is completely dependent on Garry oak. Garry oak ecosystems also support a diverse bird community, including Cooper's Hawk, Western Bluebird, and Band-tailed Pigeon. The Lewis's Woodpecker was once a resident of these open, dry woodlands on southern Vancouver Island, but it disappeared earlier in the last century (Erickson 1993). Mammals such as black-tailed deer and red squirrels also use Garry oak ecosystems.

A recent mapping project (Lea 2006) compares the current distribution of Garry oak ecosystems on southeastern Vancouver Island to the historical extent in the mid-1860s (Figure 7). Only about 10% of the area that was originally Garry oak ecosystem now remains, mostly in isolated fragments, unconnected to other Garry oak areas. Since these areas are now often dominated by invasive alien species, such as Scotch broom, introduced grasses and weeds, less than 5% of the original ecosystem remains in a near-natural condition.

Some experts suggest climate change could allow the range of Garry oak ecosystems to expand (Hebda 2004). Although the distribution of Garry oak as an individual tree species could extend over a wider range, it is unlikely other plant species associated with this ecosystem, such as snowberry, camas, and fawn lily, could compete with the many alien species that now occur on eastern Vancouver Island. The only way to maintain this ecosystem may be with extensive and costly human intervention.

Figure 7. Garry oak ecosystems in the greater Victoria area (pre-European settlement, left) and in 1997 (right).



Source: Lea (2006).

4. Indicator: Trend in the number of road crossings of streams in B.C., 2000 to 2005

This is a pressure indicator. It addresses the question: How many roads cross streams in British Columbia?

Building roads inevitably involves crossing streams and rivers. The presence of stream crossings is an indicator of impacts to stream habitat and to the movement of stream organisms, especially fish.

The most common ways to cross a stream with a road are to build a bridge or to install a culvert. A culvert is a metal, wood, plastic, or concrete pipe placed on, or embedded in, the streambed that allows water to continue under the road. The construction of either a bridge or a culvert may involve removing some of the riparian (streamside) vegetation and disturbing streambanks and streambed sediments. Sediments that enter a stream increase water turbidity (cloudiness) and reduce the oxygen available for fish eggs and other aquatic life. Sediments also fill in cobble and gravel beds that may be valuable fish spawning habitats (Newcombe and Jensen 1996; Suttle et al. 2004).

Regulations under the provincial *Forest and Range Practices Act* (FRPA) require that stream crossing construction for forestry and range activities be done only when fish are not migrating or spawning. Construction practices must protect the stream channel and bank and, after construction, materials that can have a negative effect must be removed (BCMOFR 2004). On non-forestry roads, the provincial *Water Act* legislates how work can be conducted near or in streams (BCMOE 1996). The federal *Fisheries Act* specifies unacceptable practices for construction and other work on all streams regardless of whether they are on forestry or non-forestry land (DFO 1985).

Once constructed, stream crossings—especially culverts—can cause problems for a stream ecosystem (Warren and Pardew 1998). Poor fish passage through culverts, which makes upstream fish habitat inaccessible, has been documented in numerous studies (e.g., Harper and Quigley 2000; Chestnut 2002; Gibson et al. 2005). Problems can begin with initial placement or later, as storms, floods, and high water flows can shift the position of the culvert or change the streambed.

Adverse effects from poor stream crossings affect other organisms as well as fish. Insect larvae that live on the streambed (benthic invertebrates) can be smothered by excess sediments. Resulting changes in the invertebrate community composition can then affect juvenile fish and other organisms that feed on these invertebrates (Suttle et al. 2004). It can also affect freshwater mussels, which perform an important function by filtering water. The larval stages of the mussels move through the ecosystem by attaching to the fins or gills of fish and they cannot reach upstream habitats if their host fish are unable to pass through a culvert (Watters 1996).

This indicator shows the total density of stream crossings in each ecoprovince in 2005; it also shows the increase in density in the five years from 2000 to 2005.

Methodology and Data

Data for this indicator came from the National Forest Inventory (NFI), which was developed to monitor the state of Canada's forests and to determine how they are changing over time (for more information, see *https://nfi.nfis.org/index_e.shtml*). The NFI uses a grid system to gather representative data from across the country. The data set includes settlements and infrastructure, such as roads and trails.

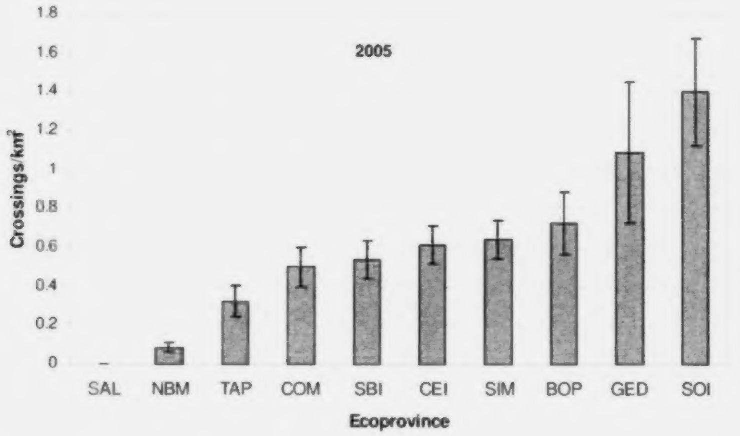
A 20 × 20 km grid has been established for B.C., giving a total of 2,420 points over the land area of the province. Each point is the centre of a 2 × 2 km square, called a photo plot. Data were assembled from Landsat satellite images of each photo plot, and 1% of the plots were also surveyed on the ground to verify the accuracy of the data obtained from the satellite images.

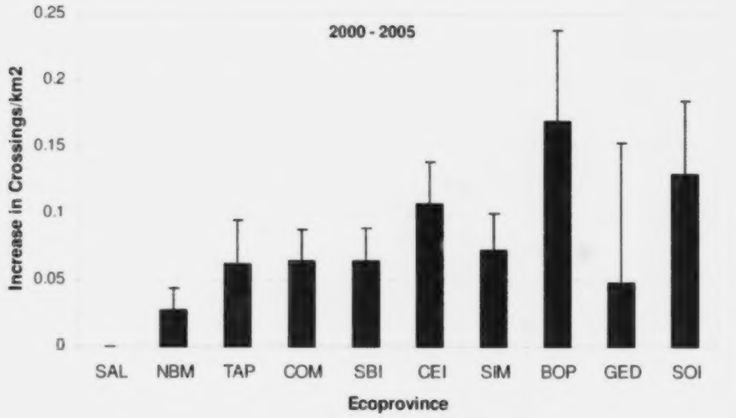
The total number of stream crossings (where a road crosses over a stream) was measured within each photo plot. The density of stream crossings was calculated for each photo plot using the area in hectares. The data were then extrapolated to arrive at a figure for the entire province. Yuan and Quayle (2006) contains details of the statistical methods used in this analysis. Results are shown in Figure 8 and Table 5.

Analysis shows an estimated total of 421,830 stream crossings in B.C. in 2000 and 488,674 stream crossings in 2005, an increase of 66,843 crossings or an average increase of 13,369 per year.

In 2005, the Southern Interior and Georgia Depression ecoprovinces had a density of more than one stream crossing per square kilometre; most other ecoprovinces had 0.5 to 0.75 crossings/km^2 (Figure 8a, Table 5). Although error bars are relatively large, the largest increase in stream crossing density occurred in the Boreal Plains, Southern Interior, and Central Interior (Figure 8b). The Georgia Depression and Northern Boreal Mountains had the lowest rates of increase. The Southern Alaska Mountains ecoprovince did not have any stream crossings in the photo plots examined during the analysis.

Figure 8. Stream crossing density (number of crossings/km^2) in B.C., by ecoprovince, (top) density in 2005; (bottom) increase in density 2000 to 2005.





Source: National Forest Inventory Photo Database. Analyzed by Forest Analysis and Inventory Branch, Ministry of Forests and Range.

Notes: Ecoprovinces are: SAL = Southern Alaska Mountains; NBM = Northern Boreal Mountains; TAP = Taiga Plains; COM = Coast and Mountains; SBI = Sub-boreal Interior; CEI = Central Interior; SIM = Southern Interior Mountains; BOP = Boreal Plains; GED = Georgia Depression; SOI = Southern Interior.

Table 5. Stream crossings density in B.C., 2000 and 2005, by ecoprovince.

	Stream crossing density (crossings/km^2)		
Ecoprovince	2000	2005	Increase 2000–2005
Southern Alaska Mountains (SAL)	0	0	0
Northern Boreal Mountains (NBM)	0.057	0.085	0.028
Taiga Plains (TAP)	0.262	0.324	0.062
Coast and Mountains (COM)	0.436	0.500	0.064
Sub-boreal Interior (SBI)	0.475	0.539	0.065
Central Interior (CEI)	0.506	0.613	0.107
Southern Interior Mountains (SIM)	0.567	0.640	0.073
Boreal Plains (BOP)	0.555	0.725	0.169
Georgia Depression (GED)	1.041	1.088	0.048
Southern Interior (-SOI)	1.272	1.401	0.129

Source: National Forest Inventory Photo Database; analyzed by Forest Analysis and Inventory Branch, B.C. Ministry of Forests and Range.

Interpretation

The ecoprovinces with the most stream crossings per square kilometre in 2005 were also the ecoprovinces with the greatest proportion of British Columbia's population. Although ecoprovince boundaries do not exactly match the regional district boundaries used for population census data, it is possible to approximate the population by combining figures for the regional districts that cover roughly the same area. The Georgia Depression ecoprovince covers the Capital, Nanaimo, Cowichan Valley, and Greater Vancouver (now Metro Vancouver) regional districts. The Southern Interior ecoprovince covers the Okanagan-Similkameen, Central Okanagan, North Okanagan, and Thompson-Nicola regional districts. Together, in 2006 these eight regional districts contained a population of 3.2 million or 75% of B.C.'s population.

The increase in stream crossings from 2000 to 2005 was greatest in the Boreal Plains ecoprovince, likely from road building for the oil and gas sector. Increases in the Southern Interior and Central Interior ecoprovinces are probably a result of growing urban development and increased logging of trees attacked by mountain pine beetle.

Fisheries and Oceans Canada conducted audits of fish passage and fish habitat in several B.C. forest districts and reported that stream crossings frequently fail to provide adequate conditions for fish. Harper and Quigley (2000) assessed 46 stream crossings in the Prince George and Port McNeil forest districts and found that 96% caused riparian habitat loss, 50% caused stream habitat loss, and 9% were impassable to fish. The authors estimated that corrugated metal pipes caused an average loss of 709 m^2 of fish habitat, bridges caused a loss of 575 m^2, and log culverts caused a loss of 414 m^2 of habitat (Harper and Quigley 2000).

This indicator shows that stream crossings may be affecting a significant amount of fish habitat every year in addition to the habitat directly altered by existing structures.

5. Secondary Indicator: Economic and conservation tenures in the intertidal areas of B.C. estuaries

This is both a pressure indicator, showing the footprint of economic activities in estuaries, and a response indicator, showing conservation tenures in estuaries for habitat protection. This indicator was fully reported in the recent state of environment report, British Columbia's Coastal Environment: 2006 (BCMOE 2006). More information and details on methodology are available in that report at *www.env.gov.bc.ca/soe/bcce/01_population_economic/tenures_intertidal.html.*

The following is a summary of the indicator.

Estuaries in B.C. account for less than 3% of the province's coastline, but these productive and diverse habitats are vitally important to many species. It is estimated that 80% of all coastal wildlife use estuaries (Kelsey 1999) and estuaries are essential habitat for salmon.

In B.C., the intertidal area is owned primarily by the Crown. Activities permitted on Crown land are formalized by allocating tenures (leases, licences, and reserves) for a defined parcel of land for a specific period of time. Tenures in the intertidal and nearshore seabed include docks, intertidal shellfish aquaculture, nearshore finfish aquaculture, and floating fishing lodges. Conservation tenures are held by conservation and government agencies to protect areas with important ecological values.

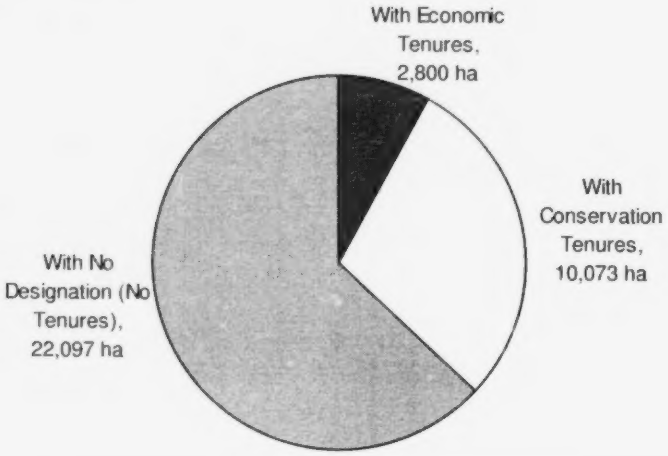
In 2004 the Canadian Wildlife Service of Environment Canada and Ducks Unlimited Canada mapped 442 of the larger estuaries on the B.C. coast and compiled the land tenure data for 440 estuaries (PECP; Ryder et al. 2003). The Serpentine/Nicomekl River (Boundary Bay) and Fraser River estuaries were not included. Details of the study methodology and results were reported in the British Columbia's Coastal Environment: 2006 report (BCMOE 2006). The survey shows the potential for impacts from economic activities in estuaries, but did not quantify impacts or differentiate between tenure types.

Of the 440 mapped estuaries, it was found that more than a third (38%) had some type of economic tenure allocated in the intertidal area (Figure 9, Table 6). Fewer estuaries (28%) had conservation tenures than had economic tenures, but the total conservation area was more than three times the area under economic tenure. Where conservation tenures exist, they usually occupy a large proportion of the intertidal area.

More estuaries (58%) in the highly populated Georgia Basin had economic tenures than in other parts of the coast. Georgia Basin estuaries also had proportionately more conservation tenures than other parts of the coast. However, the proportion was still less than half (45%), which may be a concern given the highly productive marine ecosystems in the region (Mackas and Fulton 1989) and pressure from the high population density in the region.

More than half of the total estuary intertidal area had no tenures of either type. Many of those areas have important environmental values that should be assessed as part of estuary conservation planning.

Figure 9. Area (ha) of economic and conservation tenures in 440 estuaries in B.C.



Source: Canadian Wildlife Service, Environment Canada (2004).

Table 6. Status of economic interest tenures and conservation tenures for 440 estuaries in B.C., by ecoregion.

	Number of estuaries (% of total)			Intertidal area (ha) (% of total)			
Ecoregion[a]	Total	With economic tenures	With conservation tenures	Total	With economic tenures	With conservation tenures	With no tenures
Coastal Gap	140	37 (26%)	31 (22%)	15,949.6	886.8 (6%)	4,132.5 (26%)	10,930.3 (68%)
East. Vanc. Isl.	33	23 (70%)	15 (45%)	4,603.6	824.4 (18%)	954.8 (21%)	2,824.4 (61%)
Lower Mainland	9[b]	5 (56%)	2 (22%)	653.6	26.6 (4%)	298.7 (46%)	328.3 (50%)
North. Coastal Mnts	13	4 (31%)	2 (15%)	746.5	163.6 (22%)	131.9 (18%)	451 (60%)
Pacific Ranges	73	41 (56%)	17 (23%)	5,437.3	275.6 (5%)	1,683.9 (31%)	3,477.8 (64%)
Queen Charlotte Lowlands	15	3 (20%)	9 (60%)	2,393.0	165.7 (7%)	1290.7 (54%)	936.6 (39%)
Queen Charlotte Ranges	32	7 (22%)	4 (13%)	826.3	92.6 (11%)	37.8 (5%)	695.9 (84%)
Hecate Cont'l Shelf	1	0 (0%)	0 (0%)	0.1	0.0 (0%)	0.0 (0%)	0.1 (100%)
West. Vanc. Isl.	124	44 (35%)	43 (35%)	4,359.7	364.8 (8%)	1,542.7 (35%)	2,452.2 (57%)
Total	440	164 (38%)	123 (28%)	34,969.7	2,800.1 (8%)	1,0073 (29%)	22,096.6 (63%)
Georgia Basin[c]	67	39 (58%)	30 (45%)	5,768.7	876.4 (15%)	1,397.8 (24%)	3,494.5 (61%)
Outside Georgia Basin	373	125 (34%)	93 (25%)	29,201	1,923.7 (7%)	8675.2 (30%)	1,8602.1 (64%)

[a] BCMELP 1996.

[b] This number excludes the Fraser River and Serpentine/Nicomekl River, which were not evaluated.

[c] The Georgia Basin includes all or part of the following ecoregions (number of estuaries within Georgia Basin in parentheses): Eastern Vancouver Island (26); Lower Mainland (9); Pacific Ranges (21); Western Vancouver Island (11); total 67.

6. Key Indicator: Protected area in B.C.

This is a status indicator. It addresses the question: How much area in the province has been designated as protected? This indicator provides a measure of how much of the province is in protected areas.

For this analysis, a "protected area" is defined as land or water that is legally designated as a provincial park, protected area, wildlife reserve, or ecological reserve, or other land acquired or managed for conservation by groups also included (detailed in Table 7).

Protected areas are parcels of land or water designated as protected for a variety of reasons:

- To maintain ecosystem services: Food production, water purification, waste treatment, oxygen production, climate regulation, flood protection, and erosion control, and many others (MEA 2005). Costanza et al. (1997) estimated that Earth's ecosystems provide services worth US$33 trillion each year. Reid (2001) reported that every US dollar invested in watershed protection saves from $7.50 to $200 in costs for water treatment and filtration.

- To protection of biodiversity and specific natural features: Protected areas in B.C. can include habitat for rare and endangered species (e.g., rubbing beaches for killer whales in Robson Bight, plant species at risk on Trial Island), important genetic resources (e.g., colonies of reintroduced sea otters), and unique botanical or zoological phenomena (e.g., internationally significant seabird colonies) (BC Parks 1993).
- To contribute to human health and recreation: Intact ecosystems offer recreational, aesthetic, and cultural enjoyment (e.g., Kaplan, S. 1995; Kaplan, R. 2001). Viewing and interacting with nature is now regarded as having significant benefits for human well-being and health (Maller et al. 2002). First Nations people place great cultural importance on species and ecosystems.
- To contribute to the economy: In 1999, 18.3 million recorded visits were made to B.C.'s provincial parks (BC Parks 2005). These visits, together with park operations, resulted in expenditures of $533 million and 9,100 person-years of employment. Conservation and protection programs also contribute to local economies by increasing opportunities to see wildlife and attract ecotourism. Marine protected areas (MPAs) can also provide refuges that help sustain commercially valuable adjacent fisheries (Roberts et al. 2001; Gell and Roberts 2003).
- To preserve wilderness: Protection allows species the best possible circumstances to live and to adapt to long-term changes such as global climate change. Undisturbed representative areas of major ecosystems are also critical for long-term research and monitoring (Haufler et al. 2002; Davis et al. 2003). Wilderness also has intrinsic value: ecosystems and organisms have value regardless of their role in human concerns (e.g., Takacs 1996).

In British Columbia, protected areas are intended to protect representative examples of the major terrestrial, marine, and freshwater ecosystems as well as important natural, recreational, and cultural features of the province.

Many different groups have a role in protecting areas of land and water: federal, provincial, and local governments, First Nations, nongovernment organizations, community groups, private landowners, and other individuals.

ECOLOGICAL RESERVES IN BRITISH COLUMBIA

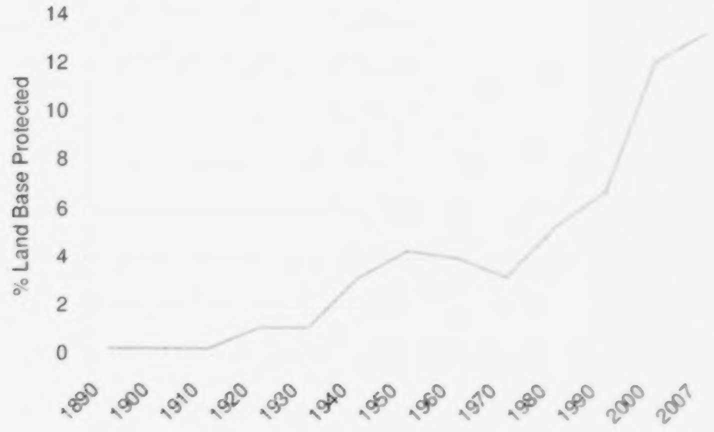
Ecological reserves are permanent sanctuaries set aside throughout British Columbia. All extractive activities are prohibited in ecological reserves. Within the province's protected area system, ecological reserves are the most highly protected and least subject to human influence. They are designated to:

- Preserve representative examples of ecosystems
- Protect rare and endangered plants and animals in their natural habitat
- Preserve unique, rare, or outstanding botanical, zoological, or geological phenomena
- Provide examples of ecosystems that have been modified by humans and offer an opportunity to study the recovery of natural ecosystems, and/or
- Ensure that ecosystems in their natural state are available for scientific research and education.

There are currently 147 ecological reserves in B.C. including wetland, marine, forested, grassland, and alpine ecological reserves. Ecological reserves cover approximately 166,918 ha and 29% of this area is marine (Friends of Ecological Reserves 2006).

In 1987, the World Commission on Environment and Development called on all nations to place 12% of their land into protected areas (WCED 1987). This target was not based on science but it served as a minimum goal to increase the amount of protected land, and the goal was adopted by several jurisdictions, including British Columbia. In 1993, the B.C. government defined a protected areas strategy that aimed to protect 12% of its land base by the year 2000. By the end of 2001 it had surpassed the goal by dedicating 11.86 million ha, or about 12.5% of the land base, as protected areas (BCMWLAP 2002). In early 2007 B.C.'s legally protected areas covered 13.4% of the land area of the province (Figure 10).

Figure 10. Increase since 1890 in protected area as a percentage of B.C.'s land base.



Source: Integrated Land Management Bureau, Ministry of Agriculture and Lands 2007.

Note: Data were compiled by decade before 1990. Includes land legally designated under the provincial *Ecological Reserve Act, Park Act, Environment and Land Use Act, Protected Area of BC Act*, and *National Parks Act*. Does not include marine areas, wildlife management areas, migratory bird sanctuaries, or regional parks. Does not include an additional approximately 570,000 ha proposed for designation as parks or protected areas that had not been legally designated at time of writing (August 2007).

Protection of marine areas was not considered specifically in the 1993 protected areas strategy and no targets for protection were set, although broad aquatic objectives were included. Worldwide, the designation of marine protected areas has lagged behind the designation of terrestrial areas. The first protected marine habitat along Canada's Pacific coast was 654 ha that was included in Strathcona Provincial Park when it was established in 1911. Little additional marine area was protected until the 1980s and 1990s when 75% of the current marine areas under protection in British Columbia were established (Lunn and Canessa 2005).

Methodology and Data

For this paper, the term "protected area" is used to describe areas of land or water that are legally protected in British Columbia through a variety of designations (Table 7). The designation an area receives defines the level of protection and depends on the objectives for the protected area and the agency creating it. For example, marine protected areas that are designated as migratory bird sanctuaries, national wildlife areas, or ecological reserves have management objectives that focus on conservation, research, and education, and place little or no emphasis on recreation and tourism. The level of protection is important for all protected areas, but particularly for marine protected areas, most of which are open to some level of recreational or commercial harvesting (e.g., Zacharias and Howes 1998; Jamieson and Levings 2001).

Table 7. Designations, legislative tools, and objectives of protected areas designated by provincial and federal agencies.

Managing agency Designation	Legislative tool	Objectives of the designation
Parks Canada		
National Marine Conservation Areas	*National Marine Conservation Areas Act*	To protect and conserve marine conservation areas of Canadian significance that represent the five Natural Marine Regions identified on Canada's Pacific coast. To encourage public understanding, appreciation, and enjoyment.
National Parks and National Park Reserves	*National Parks Act*	To maintain and/or restore the ecological integrity of natural environments. To encourage public understanding, appreciation, and enjoyment.
Fisheries and Oceans Canada		
Marine Protected Areas	*Oceans Act*	To protect and conserve: -fisheries resources, including marine mammals and their habitats; -endangered or threatened species and their habitats; -unique habitats; -areas of high biological diversity or productivity; -areas for scientific and research purposes.
Fisheries Closure	*Fisheries Act*	To manage and regulate fisheries, conserve and protect fish habitat, and prevent pollution of waters frequented by fish.
Canadian Wildlife Service, Environment Canada		
Migratory Bird Sanctuaries	*Migratory Birds Convention Act*	To protect habitats that migratory birds use for breeding, feeding, migrating, and overwintering.
National Wildlife Areas; Marine Wildlife Areas	*Canada Wildlife Act*	To protect and conserve areas that are nationally or internationally significant for all wildlife, but focusing on migratory birds.
B.C. Ministry of Environment		
Ecological Reserves	*Ecological Reserve Act*	To protect: -representative examples of B.C.'s environment -rare, endangered, or sensitive species or habitats -unique, outstanding, or special features -areas for scientific research and education.
Provincial Parks	*Park Act*	To protect: -representative examples of terrestrial and marine diversity, and recreational and cultural heritage; -special natural, cultural heritage, and recreational features.
Protected Areas	*Environment and Land Use Act*	To protect: -representative examples of terrestrial and marine diversity, and recreational and cultural heritage; -special natural, cultural heritage, and recreational features.
Conservancies	*Park Act or Protected Area of BC Act*	To be set aside for: -the protection and maintenance of their biological diversity and natural environments; -the preservation of social, ceremonial, and cultural uses of first nations; -the protection and maintenance of their recreational uses, and -to ensure that development or use of their natural resources occurs in a sustainable manner.
Recreation Areas	*Park Act* (Park and Recreation Area Regulation)	To provide opportunities for public recreational use.
Wildlife Management Areas	*Wildlife Act*	To conserve and manage areas of importance to fish and wildlife. To protect endangered or threatened species and their habitats, whether resident or migratory, of regional, national, or global significance.

Sources: Governments of Canada and British Columbia 1998; Department of Justice Canada 2005; B.C. Ministry of Labour and Citizens' Services 2005.

For this analysis (Figure 11, Tables 8 and 9), GIS coverages of provincial ecosection boundaries were used to determine the location of individual protected areas in B.C. Overlaying 1:20,000 scale protected areas with 1:250,000 ecosections resulted in "slivers" of land where the boundaries at different scales did not always match exactly. These slivers, amounting to a total of 2,188 ha of protected area, were excluded from analysis.

Of the ecosections, 127 are entirely terrestrial. There are 12 marine ecosections: 2 exclusively so, and 10 that meet the shore and include small amounts of land in the form of islands and islets. These small amounts of land in a vast sea are not particularly representative of land or sea, and are so small as to be inconsequential to the overall analysis. For these reasons, they were excluded from Table 8. The protected marine area was calculated as a percentage of the marine portion of that ecosection, and the terrestrial protected area was calculated as a percentage of the land portion. Where an ecosection boundary bisected a protected area, the relevant amount of protected land or ocean was calculated for each ecosection.

The marine analysis (Table 9) includes all types of national and provincial protected areas described in Table 7. Marine area was considered to be that portion of a protected area that occurred below the high tide line (i.e., intertidal). The analysis was limited to areas where protected status was finalized, and recent changes were taken into account where possible. Both Haida Gwaii National Marine Conservation Area Reserve (342,000 ha) and Bowie Seamount Pilot Marine Protected Area (609,223 ha) were included. However, the proposed Scott Islands Marine Wildlife Area (6.2 million hectares) and proposed marine area in Gulf Islands National Park (3,381 ha) were excluded because the protection of these areas is still a matter of negotiation. Rockfish Conservation Areas were also excluded because they were considered to be a fisheries management tool rather than a conservation area.

Whereas the marine analysis in this paper includes the full scope of areas identified in Table 7, the terrestrial analysis is confined to national parks and park reserves, provincial parks, protected areas, ecological reserves, conservancies, and recreation areas. Terrestrial measurements do not include subtidal areas. Private protected areas and those created by local governments are not included but are currently only a very small portion of the overall protected area.

Figure 11. Ecosections in B.C. showing percentage of land area protected.

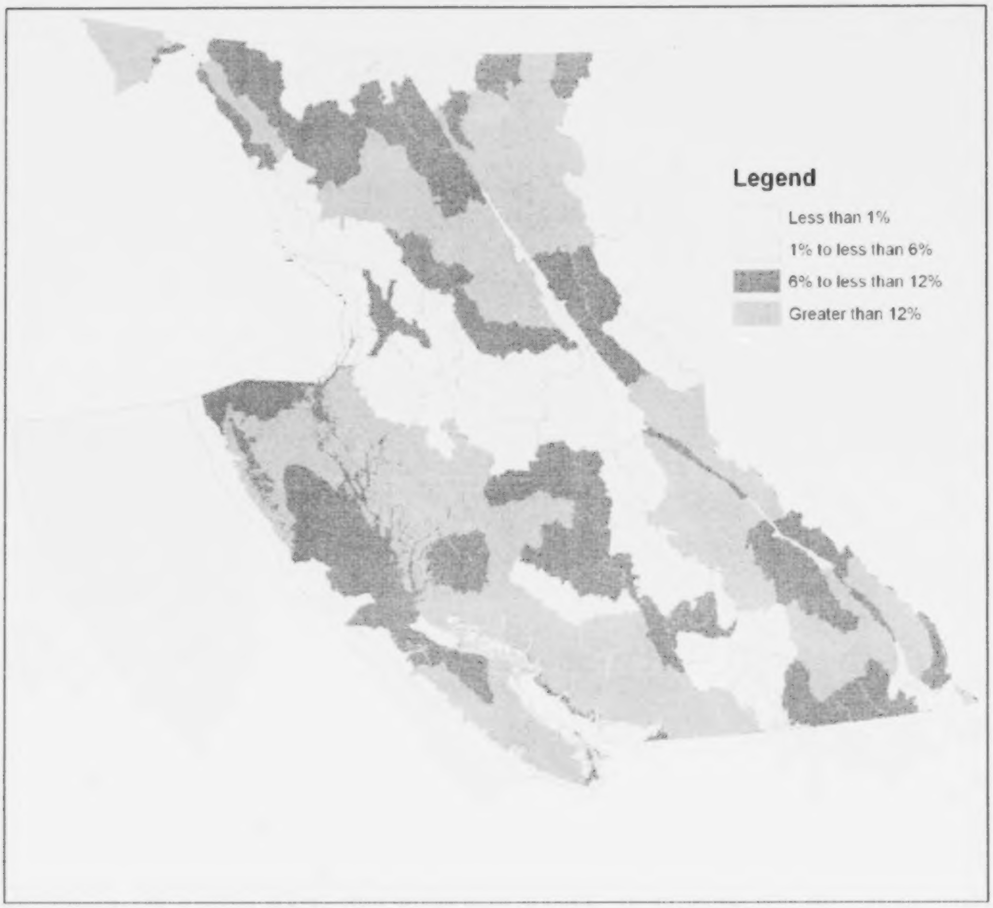

Legend
Less than 1%
1% to less than 6%
6% to less than 12%
Greater than 12%

Table 8. Area and percentage of land protected, by ecosection. Marine ecosections that include small amounts of land are excluded.

Ecosection	Total area (ha)	Protected area (ha)	% of area protected
Alsek Ranges	354,153	353,255	100
Babine Upland	2,001,852	75,517	4
Big Bend Trench	146,366	1,064	1
Bowron Valley	689,436	25,867	4
Bulkley Basin	1,340,875	44,421	3
Bulkley Ranges	598,783	0	0
Cariboo Basin	908,178	10,748	1
Cariboo Mountains	1,415,727	566,514	40
Cariboo Plateau	837,364	14,222	2
Cassiar Ranges	1,757,488	148,584	8
Central Boundary Ranges	845,205	9,666	1
Central Chilcotin Ranges	1,052,803	325,072	31
Central Columbia Mountains	1,431,049	311,578	22
Central Pacific Ranges	2,070,887	132,532	6
Central Park Ranges	554,987	49,249	9
Chilcotin Plateau	1,659,818	68,928	4
Clear Hills	1,222,155	7,829	1
Cranberry Upland	428,138	1,343	<1
Crown of the Continent	55,918	10,774	19
East Kootenay Trench	261,819	2,695	1
Eastern Muskwa Ranges	1,694,095	675,196	40
Eastern Pacific Ranges	1,354,150	249,288	18
Eastern Purcell Mountains	644,886	118,283	18
Eastern Skeena Mountains	768,055	56,727	7
Elk Valley	359,312	22,958	6
Etsho Plateau	872,505	65	<1
Finlay River Trench	168,555	5,713	3
Flathead Valley	176,452	0	0
Fort Nelson Lowland	2,444,612	11,217	<1
Fraser Lowland	306,976	7,449	2
Fraser River Basin	236,761	22,097	9
Front Ranges	212,853	79,828	38
Georgia Lowland	123,891	10,791	9
Guichon Upland	287,690	5,984	2

Ecosection	Total area (ha)	Protected area (ha)	% of area protected
Halfway Plateau	1,011,368	459	<1
Hart Foothills	950,180	38,614	4
Hecate Lowland	1,537,247	322,012	21
Hozameen Range	466,253	96,009	21
Hyland Plateau	503,620	37,828	8
Kechika Mountains	634,967	55,892	9
Kechika River Trench	140,665	74,281	53
Kimsquit Mountains	758,474	169,098	22
Kiskatinaw Plateau	636,341	20,845	3
Kitimat Ranges	2,257,399	619,049	27
Kluane Ranges	375,720	375,720	100
Leeward Island Mountains	933,112	151,209	16
Leeward Pacific Ranges	362,049	86,395	24
Liard Plain	1,243,111	8,439	1
Manson Plateau	1,103,863	73,568	7
Maxhamish Upland	443,115	27,516	6
McGillivray Range	165,931	47	<1
McGregor Plateau	607,210	3,805	1
Meziadin Mountains	439,143	2,159	<1
Misinchinka Ranges	657,045	66,067	10
Muskwa Foothills	1,086,761	339,831	31
Muskwa Upland	1,258,569	50,228	4
Nahwitti Lowland	337,201	20,747	6
Nanaimo Lowland	298,936	4,664	2
Nass Basin	619,388	38,080	6
Nass Mountains	1,248,626	59,137	5
Nazko Upland	1,815,455	210,132	12
Nechako Lowland	1,692,614	69,333	4
Nechako Upland	754,670	522,384	69
Nicola Basin	428,003	2,349	1
Northern Boundary Ranges	568,010	63,471	11
Northern Hart Ranges	564,177	42,219	7
Northern Island Mountains	577,676	52,719	9
Northern Kootenay Mountains	1,591,785	167,497	11
Northern Okanagan Basin	290,555	15,337	5
Northern Okanagan Highland	707,279	26,092	4
Northern Omineca Mountains	1,388,499	205,290	15

Ecosection	Total area (ha)	Protected area (ha)	% of area protected
Northern Pacific Ranges	982,977	86,923	9
Northern Park Ranges	713,821	230,124	32
Northern Shuswap Highland	1,016,467	164,728	16
Northern Skeena Mountains	1,715,667	54,079	3
Northern Thompson Upland	270,455	14,473	5
Northwestern Cascade Ranges	44,440	4,571	10
Okanagan Range	481,803	68,029	14
Outer Fjordland	435,923	17,819	4
Parsnip Trench	435,402	11,921	3
Pavilion Ranges	439,924	34,242	8
Peace Foothills	654,939	42,024	6
Peace Lowland	924,144	3,758	<1
Petitot Plain	507,910	20,384	4
Queen Charlotte Lowland	327,644	68,656	21
Queen Charlotte Ranges	352,820	117,800	33
Quesnel Highland	773,583	114,399	15
Quesnel Lowland	576,723	6,562	1
Rabbit Plateau	333,513	22,204	7
Selkirk Foothills	764,602	87,088	11
Shuswap Basin	295,909	3,454	1
Shuswap River Highland	477,700	14,809	3
Sikanni Chief Upland	1,271,158	35,475	3
Simpson Upland	18,764	0	0
Skidegate Plateau	339,255	38,390	11
Southern Boreal Plateau	2,309,335	1,277,589	55
Southern Boundary Ranges	722,943	26,874	4
Southern Chilcotin Ranges	600,610	87,305	15
Southern Columbia Mountains	367,779	41,662	11
Southern Gulf Islands	97,566	7,036	7
Southern Hart Ranges	899,672	181,544	20
Southern Okanagan Basin	82,356	11,523	14
Southern Okanagan Highland	53,968	980	2
Southern Omineca Mountains	1,100,999	154,278	14
Southern Pacific Ranges	1,064,661	175,716	17
Southern Park Ranges	1,069,263	368,812	34
Southern Purcell Mountains	543,007	39,484	7
Southern Skeena Mountains	726,990	34,138	5

Ecosection	Total area (ha)	Protected area (ha)	% of area protected
Stikine Highland	588,700	14,045	2
Stikine Plateau	1,512,791	128,378	8
Tagish Highland	224,658	0	0
Tahltan Highland	627,036	90,246	14
Tatshenshini Basin	311,466	211,541	68
Teslin Basin	502,849	199	<1
Teslin Plateau	1,256,908	99,163	8
Thompson Basin	312,127	20,989	7
Tranquille Upland	299,603	22,588	8
Trout Lake Plain	154,451	0	0
Tuya Range	1,168,326	14,002	1
Upper Columbia Valley	179,990	20,563	11
Upper Fraser Trench	261,662	18,850	7
Western Chilcotin Ranges	525,637	299,537	57
Western Chilcotin Upland	828,602	111,076	13
Western Muskwa Ranges	1,013,877	168,900	17
Western Okanagan Upland	267,988	6,454	2
Whitehorse Upland	37,959	0	0
Windward Island Mountains	1,077,615	201,719	19
Total*	94,685,750	12,643,436	13.4

Source (terrestrial data): Chief Resource Information Office Integrated Land Management Bureau, Ministry of Agriculture and Lands 2007. Terrestrial protected areas include land designated under the provincial *Ecological Reserve Act, Park Act, Environment and Land Use Act, Protected Area of BC Act,* and *National Parks Act.* They do not include marine areas, wildlife management areas, migratory bird sanctuaries, or regional parks. Marine ecosections that include a small amount of land are not included.

* Calculations for total land area of B.C. may differ from other indicators in this report due to the different map scales used for each analysis. Area does not include approximately 570,000 ha that are proposed for designation as parks or protected areas, but had not been legally designated at time of writing (August 2007).

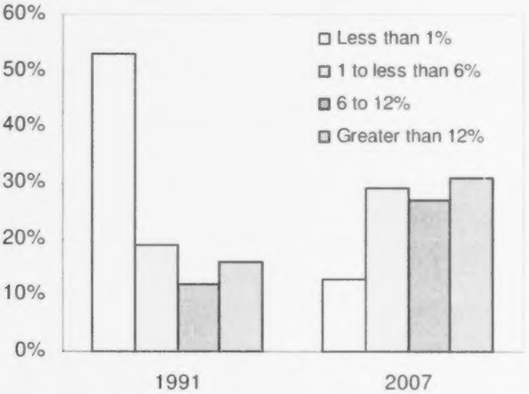
Table 9. Area and percentage of intertidal or subtidal areas protected within marine ecosections.

Ecosection	Total area (ha)	Protected area (ha)	% of area protected
Continental Slope	3,330,903	175,806	5
Dixon Entrance	1,088,196	60,482	6
Hecate Strait	1,279,857	163,290	13
Johnstone Strait	240,769	8,752	4
Juan de Fuca Strait	150,367	2,042	1
North Coast Fjords	957,954	59,120	6
Queen Charlotte Sound	3,640,182	256,515	7
Queen Charlotte Strait	219,707	7,761	4
Strait of Georgia	814,597	35,168	4
Subarctic Pacific	17,097,858	609,223	4
Transitional Pacific	14,850,461	9,707	<1
Vancouver Island Shelf	1,669,068	89,062	5
Provincial Total	45,339,919	1,476,927	3.3

Source: Coastal Planning, Integrated Land Management Bureau, Ministry of Agriculture and Lands (marine protection area data) 2007.

Note: Includes Haida Gwaii National Marine Conservation Area Reserve (342,000 ha) and Bowie Seamount Pilot Marine Protected Area (609,223 ha). Does not include the proposed Scott Islands Marine Wildlife Area (6.2 M ha), the proposed marine area in Gulf Islands National Park (3381 ha), and Rockfish Conservation Areas. Some marine ecosections contain small amounts of land that was not included in this total.

Figure 12. Percentage of terrestrial ecosections with protected area status.



Source: Integrated Land Management Bureau, Ministry of Agriculture and Lands.

Interpretation

Ecosystems within British Columbia are not equally represented by the system of protected areas (Tables 8 and 9), but representation has improved since 1991.

- Most of the 127 terrestrial ecosections in B.C. are represented, but 6 ecosections have no protected areas. In most cases, ecosections with no protected areas are transboundary, with only a small part of the ecosection found in British Columbia.
- More than half of the terrestrial ecosections in 2007 have 1–12% of their area protected, and almost one-third have more than 12% protected. This is a substantial increase over 1991 when one-third of the ecosections had 1–12% protected, and only one-sixth had more than 12% protected (Figure 12).
- In 2007, 16 terrestrial ecosections had less than 1% of their area protected, whereas in 1991 more than half of the ecosections had less than 1% of their area protected.
- Seven terrestrial ecosections have more than 50% of their area protected and two of these have nearly 100% protection—the Alsek and Kluane Ranges in the northwestern corner of the province, which include approximately 700,000 ha within the Tatshenshini-Alsek Park. In its entirety, this park stretches north into the Yukon and Alaska for nearly 8.5 million hectares.
- Marine ecosystems are the least represented with 7 of 12 marine ecosections have less than 5% of their area protected (Table 9).

Critics of British Columbia's protected areas system are concerned that the more economically valuable ecosystems are under-represented (Soule and Sanjayan 1998) compared to mountaintops and wetlands. Many of the best represented terrestrial ecosections (e.g., Cariboo Mountains, Eastern Muskwa Ranges, Front Ranges, Southern Pacific Ranges, Western Chilcotin Ranges) tend to be rugged and mountainous; however, this is the character of much of the province. Some plateau and upland areas (e.g., Southern Boreal Plateau, Nechako Upland) are also well represented.

The area protected in the Transitional Pacific ecosection increased with the addition of the Endeavour Hydrothermal Vents (DFO 2005). The Transitional Pacific ecosection still has less than 1% protected. Other marine ecosections with less than 1% of their area protected are Continental Slope, Dixon Entrance, and Hecate Strait. Overall, little or none of the western and northern marine ecosections of B.C. are currently protected.

Recently there have been two important developments:

- On the central coast, 45 new conservancy areas of approximately 700,000 ha have been finalized, with 65 more announced but not yet final (the latter are not included in this analysis). When the 65 new areas are complete, they will contribute an additional 500,000 ha to the current protected area system.
- The government of Canada signed an agreement with the Haida Nation in 2007 to work together in developing the Bowie Seamount Pilot Marine Protected Area. The Bowie Seamount Pilot Marine Protected Area was more than 600,000 ha, the largest in British Columbia. It has been described as an "isolated island of biodiversity" in the deep ocean.

After a slight decline in protected area during the 1960s and 1970s (due to land taken out of provincial parks for hydroelectric and forestry uses), B.C.'s protected areas have steadily increased over the past 100 years (Figure 12). The proportion of the province protected has more than doubled since 1991 when approximately 6% of the province's land base was protected. Overall, at time of writing (August 2007), legally designated terrestrial protected areas account for 13.4% of the provincial land base. This does not include the approximately 570,000 ha in about 65 proposed conservancies that had not been legally designated. Including all proposed conservancies would show an approximate figure of 14% of the land base in protected areas. Nationally, in 2006, Canada had just over 9% of its land base in protected areas (Natural Resources Canada 2006). Marine protected areas have not fared as well, accounting for only 3.3% of the marine area of the province in 2007.

Although the area protected in B.C. is relatively high by Canadian standards, the percentage of protected land required to maintain the province's ecosystems and biodiversity may be considerably more than current coverage (Soule and Sanjayan 1998; Scudder 2002). Noss (1983) states that the amount of protected area required to adequately maintain any ecosystem will depend on the level of disturbance in the area surrounding the reserve. Thus, assessing whether we are protecting enough of our land base, in the right places, to capture a range of ecological values is only the first step in conserving ecosystems and biodiversity. Maintaining ecosystem processes and preventing species from going extinct requires attention to more than just the amount and location of protected areas (Noss 1995). The effectiveness of protection depends on the proximity to other protected areas, quality of the environment around the protected area, and the impact of internal and external stressors on the protected area.

Some researchers suggest that conservation targets approaching 50% of the land base may be needed to maintain biodiversity (Soule and Sanjayan 1998). Studies of terrestrial ecosystems suggest that such large reserves are desirable for wilderness protection because they have been shown to be more effective at conserving a diverse array of species (e.g., MacArthur and Wilson 1967; Newmark 1987; Gurd et al. 2001). Target percentages have also been suggested for marine areas; for example, the World Parks Congress of 2003 called for strict protection or "no-take" areas in 20–30% of each type of marine and coastal habitat, which is almost 10 times more than the current extent of marine protection in British Columbia (WPC 2003).

Even large protected areas can be ineffective for conserving some large mammals on land and at sea (Noss 1995; Gerber et al. 2005). In the long term, viable populations of grizzly bears, cougars, wolves, and whales that live in B.C. cannot be conserved by protected areas alone because collectively they require more space than any single protected area can provide (Grumbine 1990; McLellan and Hovey 2001; Killer Whale Recovery Team 2005). Ideally, a protected landscape should include a network of adjoining habitats in large core protected areas, along with functional corridors between protected areas, surrounded by buffer zones of sustainably managed areas and privately protected land (Woodley 1997; Noss et al. 1999).

One recent Canadian study found that protected land areas of about 31,000 ha would be large enough to conserve mammal species that were sensitive to disturbance if the landscape surrounding the protected area (within 50 km) contained at least 180,000 ha of useful habitat (Wiersma et al. 2004). Some scientists suggest that even the low extent of marine protection in British Columbia effectively may be many times smaller, because some B.C. marine protected areas allow activities such as dredging, bottom trawling, and commercial harvest (Jessen and Symington 1996). The relative intactness of the landscape within and outside of protected areas is discussed in the following indicator.

IMPACT OF CLIMATE CHANGE ON BC'S PROTECTED AREAS

As mentioned in previous indicators, climate change is likely to have a profound effect on the ecosystems in British Columbia. What would these ecosystem changes mean for B.C.'s protected areas? Protected area strategies generally try to achieve a representation of ecosystem diversity, usually based on a broad, regional ecosystem with distinctive climate and soil conditions, often referred to as a biome.

One study (Lemieux and Scott 2005) suggested that global warming will place anywhere from 27 to 79% of B.C.'s provincial parks into a different biome from what they are now. A similar study (Scott et al. 2002) suggests there is potential for substantial change in the biome representation in Canada's national park system, including BC's seven national parks. This has important implications on future protected area planning which may need to consider not only shifting biome boundaries, but a whole different suite of communities and ecosystems than those in existence now.

Supplementary Information: Protected forests in B.C.

Forests cover two-thirds of British Columbia's land area. Many of the province's diverse plants and animals depend on these forests for their habitat requirements. To provide a broad range of habitats necessary to protect the biodiversity in the province, it is important to protect forests of different ages and elevations.

The area of forest that is legally protected has more than doubled in the past 16 years, from 2.5 million ha (4.2% of B.C.'s forests) in 1991 to 5.7 million ha (9.7%) in 2007 (Figure 13). This includes an area on the central and north coast known as the Great Bear Rainforest which was added to B.C.'s protected area system in 2006. B.C. now has a larger proportion of forests protected than the Canadian average: about 8% of Canada's forests are legally protected (Natural Resources Canada 2006).

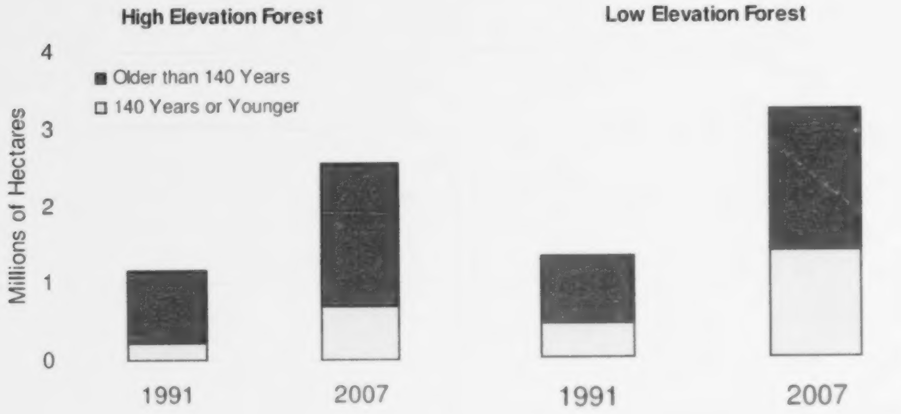
B.C.'s mountainous terrain means that elevation strongly influences the type of forest that will grow. For this analysis, a "high-elevation forest" is any forest within the Mountain Hemlock, Engelmann Spruce–Subalpine Fir and Spruce-Willow-Birch biogeoclimatic zones (including some treed parts of the Alpine zone), and "low-elevation forests" are those within any of the other 10 forested biogeoclimatic zones. More information on the biogeoclimatic zones and their associated elevations are available in Meidinger and Pojar 1991 (also see *www.for.gov.bc.ca/hre/becweb*). An analysis of older forests by biogeoclimatic zones, elevations, and coastal versus interior forests is available from the Ministry of Forests and Range (BCMOFR 2006a) at *www.for.gov.bc.ca/hfp/sof/2006/*.

High-elevation forests cover 16.8 million ha, accounting for more than a quarter of the province's forests. The area of protected high-elevation forests has more than doubled from 1.15 million ha (6.9% of this forest type) in 1991 to 2.54 million ha (15.1%) in 2007. Of the protected high-elevation forest, 10.9% is older forest (more than 140 years old) and 4.2% is younger forest (up to 140 years old). This is an increase from 5.6% and 1.3%, respectively, in 1991.

Older forests at high elevations have been less affected by timber harvesting than older forests at low elevations because they have been less accessible and less economical to harvest. However, high-elevation forests have important ecological and wildlife values. They provide habitats for many species, such as Williamson's sapsucker, caribou, and wolverines listed by the BC Conservation Data Centre as at risk of extirpation or extinction (CDC 2007).

Low-elevation forests cover 42.3 million ha or more than 70% of all forests in the province. Older forests at low elevation are under greater pressure from forestry, agriculture, and expanding urban development, which makes it challenging to increase the area protected. The area of protected low-elevation forests has also more than doubled from 1.31 million ha (3.0% of low-elevation forests) in 1991 to 3.20 million ha (7.6% of low-elevation forests) in 2007, with 4.3% being older forest and 3.3% being younger forest. This is up from 2.0% older forests and 1.0% younger forests in 1991.

Figure 13. Area of high-elevation and low-elevation forests that are protected in B.C., by age class.



Source: Ministry of Forests and Range. State of Forests 2007.

7. Secondary Indicator: Proportion of ecologically intact land within protected areas in B.C.

This is an impact indicator. It addresses the questions: How much of the land area of the province is considered intact (i.e., "wilderness") ecosystems? How much of the intact area is protected?

The presence of roads is a meaningful indicator for assessing the ecological integrity of terrestrial ecosystems. This is because roads open up areas to other types of human disturbances and have cumulative impacts that persist as long as the roadbed is in place (Noss 1995). In B.C., a lack of roads is indicative of ecological integrity because roads accompany most of the province's high-impact activities (i.e., industrial forestry, mining, agriculture, urbanization). In addition, roads affect natural ecosystems and wildlife by disturbing and destroying habitat, acting as barriers to wildlife movement, increasing mortality through roadkill and illegal harvest, altering water flow patterns, and increasing pollution and sedimentation (Crist et al. 2005; Wheeler et al. 2005). By fragmenting habitat and reducing the landscape connectivity necessary for movement and dispersal of animals and plants, roads impede gene flow among populations and reduce the resilience of some species populations to disturbance (Simberloff et al. 1992). Roads may also provide avenues for invasion by alien species (e.g., Prasad 2000) and may affect animal behaviour. For example, grizzly bears may avoid parts of their habitat to avoid vehicle traffic (McLellan and Shackleton 1989; McLellan 1990). Roads also have other effects on stream habitats (see also Indicator 4). Pollution from fine sediments can alter the physical habitat of streams by changing channels and clogging gravel beds, and road runoff can contain heavy metals, motor oil, and de-icing salt (Wheeler et al. 2005). In addition, the presence of roads and railways near streams increases the risk of toxic chemical spills.

This indicator shows how much of B.C. is intact (roadless) and how much of this intact area is currently protected in provincial and national protected areas.

Methodology and Data

Intact areas were defined as areas of at least 2,000 ha that are more than 5 km away from roads. Because no definitive effective size has been set for a protected area, the 2,000-ha minimum size was chosen on the theory that larger reserves are more effective at conserving biodiversity (MacArthur and Wilson 1967; Newmark 1987; Gurd et al. 2001). The 2,000 ha (20 km^2) figure used here is a conservative minimum size for some species, but it is less representative of the space demands of some large vertebrate species. For example, grizzly bears may have home ranges of 40 to more than 2,000 km^2 (Ross 2002).

The minimum 5-km distance from a road follows the methodology used in a similar analysis of roadlessness (Lee et al. 2003) that set a minimum polygon width of 10 km. This 10 km width effectively ensured that "roadless areas" were defined as being a minimum of 5 km from the nearest road. The 5 km buffer also allows the influence of roads encroaching on protected areas to be incorporated into the analysis (in addition to the roads within protected areas). The size and number of areas defined as intact were determined using provincial GIS data that incorporated layers of data for roads from the 1:20,000 TRIM II (Terrain Resource Information Management, 2005) transportation layer, provincial ecoprovinces, and provincial and national protected areas.

The road data included paved and dirt roads, railways, runways that are currently used by vehicle traffic, and seismic lines. Seismic lines are straight or meandering pathways, 1.5 to 7 m wide and at least 2 km long, that are used in oil and gas exploration. The following were not included in the analysis: ferry routes, overgrown roads, cart and tractor tracks, winter tracks and trails, footpaths, portage trails, ski and bike trails, equestrian and pedestrian hiking trails, and any proposed trails and roads. In 2005, a comparison of satellite images with TRIM data found that the TRIM II database does not capture all current roads (BCMOFR, unpubl. data). The percentage of roads not in the TRIM II database varies from 6% (Georgia Depression and Southern Interior) to 15% (Coast and Mountains) and averages 10% (Table 10). These uncaptured roads appear to be largely private forestry roads. Thus, this indicator shows a conservative estimate of the presence of roads in B.C.

Table 10. Roads not captured in TRIM II data set, by ecoprovince.

Ecoprovince	% of roads not in TRIM II
Boreal Plains	11.3
Central Interior	11.4
Coast and Mountains	15.2
Georgia Depression	5.7
Northern Boreal Mountains	8.5
Southern Alaska Mountains	Not analyzed
Southern Interior	6.0
Southern Interior Mountains	9.8
Sub-boreal Interior	11.4
Taiga Plains	9.0

Sources: TRIM II data from Integrated Land Management Bureau, Ministry of Agriculture and Lands 2005. Non-TRIM data from National Forest Inventory (which uses Landsat satellite images). Analysis initiated by Forest Analysis and Inventory Branch, Ministry of Forests and Range.

Protected areas in this indicator include provincial parks (Classes A, B, and C), ecological reserves, protected areas, recreation areas, and national park reserves. Not included in the analysis were community watersheds, private reserves, regional parks, wildlife reserves, wildlife and management areas. Designations that do not provide protection under Canadian or B.C. legislation also were not included (e.g., UNESCO Biosphere Reserves).

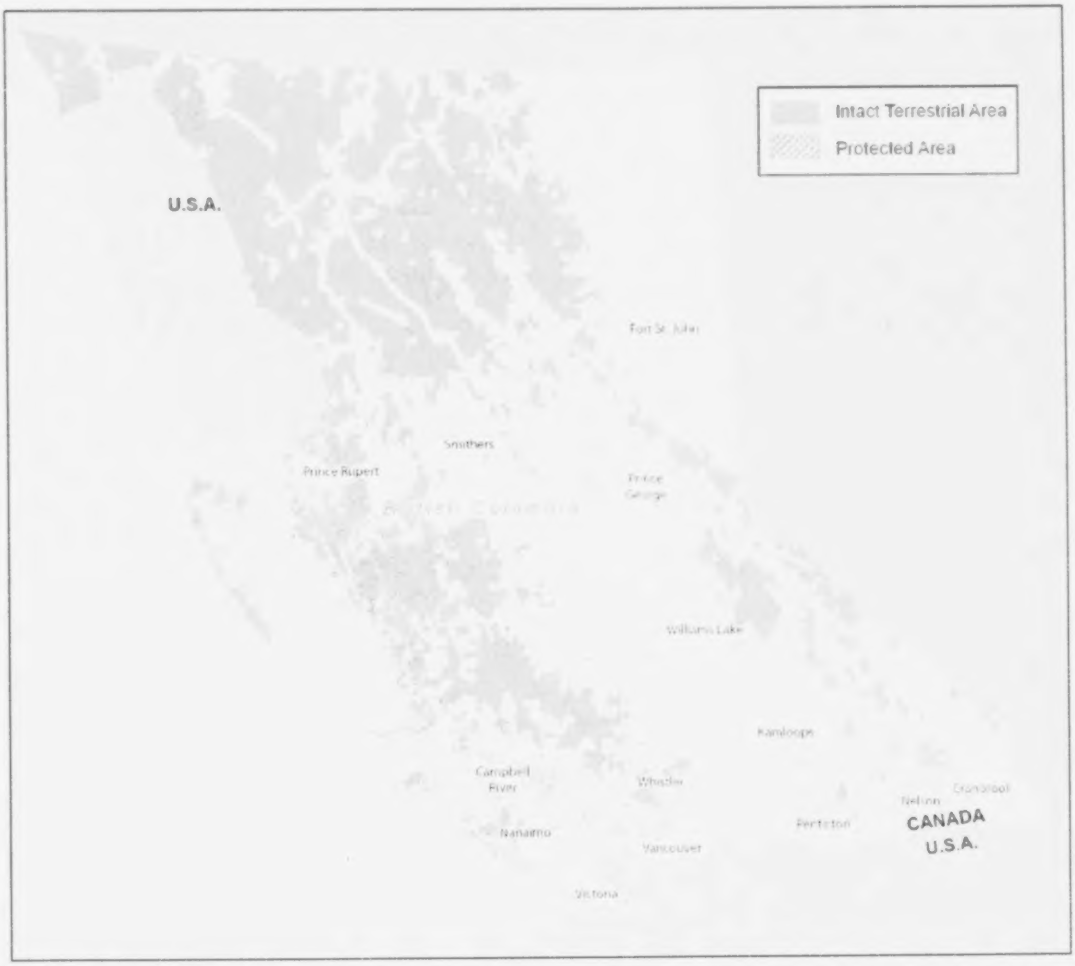
The "intact areas" layer was created by removing a buffer zone of 5 km on each side of all roads shown in TRIM II. The resulting polygons were retained if they were 2,000 ha or larger. If a small polygon was adjacent to a polygon in another ecoprovince and together the area exceeded 2,000 ha, the small polygon was included in the analysis. The ecoprovince and intact data layers were combined to create a map of the intact areas in each ecoprovince. This information was then combined with the protected areas data layer to determine the amount of intact land within protected areas (Figure 14). Marine portions of each primarily terrestrial ecoprovince were not included (but see the discussion of marine intact areas in the supplementary information below).

About 31% of the land area in B.C. is intact or roadless and 13% is protected, but only 8% of the province is both protected and intact (Table 11). Over one-third of the protected land area in B.C. is within 5 km of a road.

One transboundary ecoprovince, the Southern Alaska Mountains, is entirely protected and 98% intact within B.C. However, this ecoprovince accounts for only 0.4% of the province's land area. In the remaining nine terrestrial ecoprovinces, the proportion of protected land area varies from 1% for the Boreal Plains to 20% for the Northern Boreal Mountains (Figure 14, Table 11). The proportion of land area that remains intact ranges from none for the Boreal Plains to 70% of the Northern Boreal Mountains. Along with the Boreal Plains, three other ecoprovinces have very low proportions of intact land remaining: Taiga Plains, Georgia Depression, and Southern Interior.

When this indicator was reported in 2006, numbers were slightly different for the areas of total land and intact land for the Georgia Depression and the Coast and Mountains (BCMOE 2006) ecoprovinces because different methods used to analyze the spatial data.

Figure 14. Intact ecosystems and protected areas in British Columbia. The designation of intact ecosystems is based on the absence of human use, including roadways.


Intact Terrestrial Area
Protected Area
U.S.A.
Fort St. John
Smithers
Prince Rupert
British Columbia
Prince George
Williams Lake
Kamloops
Campbell River
Whistler
Nanaimo
Vancouver
Victoria
Penticton
Nelson
Cranbrook
CANADA
U.S.A.

Source: For terrestrial areas, see the Integrated Land Management Bureau, Ministry of Agriculture and Lands data sources listed in Table 7.

Table 11. Ecologically intact areas (more than 5 km from a road and larger than 2,000 ha) and protected land areas in the terrestrial ecoprovinces of B.C.

	Area of ecoprovince (ha)				Proportion of ecoprovince (%)				
Ecoprovince	Total land	Intact	Protected	Intact protected	Intact	Protected	Intact protected	Protected area that is intact	Both protected and intact
Southern Alaska Mountains	352,612	345,114	352,612	345,114	97.9	100.0	100.0	97.9	97.9
Northern Boreal Mountains	18,899,400	13,161,706	3,830,560	2,967,349	69.6	20.3	22.5	77.5	15.7
Central Interior	11,135,700	1,716,072	1,645,750	1,062,466	15.4	14.8	61.9	64.6	9.5
Coast and Mountains	17,652,697	7,915,739	2,554,730	1,494,173	44.8	14.5	18.9	58.5	8.5
Southern Interior Mountains	13,837,400	2,148,324	2,388,550	1,091,487	15.5	17.3	50.8	45.7	7.9
Georgia Depression	1,795,883	52,262	194,457	50,361	2.9	10.8	96.4	25.9	2.8
Sub-boreal Interior	13,878,700	3,917,895	903,390	369,061	28.2	6.5	9.4	40.9	2.7
Southern Interior	5,645,030	213,869	495,662	112,288	3.8	8.8	52.5	22.7	2.0
Taiga Plains	6,952,320	60,255	144,885	15,375	0.9	2.1	25.5	10.6	0.2
Boreal Plains	3,794,010	0	32,896	0	0	0.9	0	0	0
Provincial total*	93,943,752	29,531,236	12,544,135	7,506,959	31.4	13.4	26.3	59.8	8.0

Source: Integrated Land Management Bureau, Ministry of Agriculture and Lands.

* Calculations for total land area may differ from other indicators in this report because different map scales were used for each analysis.

Interpretation

The largest tracts of intact land, in terms of the roadless metric used in this indicator, are along the central and north coasts and in the northwestern sector of the province. Large portions of these intact lands are protected and embedded in large tracts of intact land that provide corridors between the protected areas. Some large areas of intact land also occur along the Rockies and adjacent mountain ranges in the east of the province. Much of this intact area, however, is already within protected areas. There is less intact land between protected areas in the eastern part of the province than in the northwest and central coast of the province.

The Taiga Plains ecoprovince has no intact land remaining and the Boreal Plains ecoprovince has less than 1% remaining. Both of these ecoprovinces are in northeastern B.C. where seismic lines criss-cross the landscape. Unlike roads, seismic lines are not maintained as clearings, but they fragment the landscape, carving open areas through formerly unbroken habitats.

At least half of the intact area in the central interior, southern interior, lower mainland, and most of Vancouver Island is also in protected areas, which are often surrounded by roads. Therefore, each protected polygon (which could include more than one protected area if their boundaries adjoin) is isolated from other intact areas. For example, only 8% of remaining grasslands in the southern and central interior are located within protected areas (see Indicator 1 "Status of grassland habitats"). The small amount of remaining intact area in the southern and central interior makes it unlikely that the proportion of protected grasslands could be significantly increased over the current level.

This is a concern because lack of connectivity between intact areas may leave the plants and animals that occur there more vulnerable to extinction and to problems arising from genetic isolation (Simberloff et al. 1992). It also reduces the ability of a species to move to more favourable habitat in response to climate change or other pressures. Noss (1983) states that the amount of protected area required to adequately maintain any ecosystem will depend on the level of disturbance in the area surrounding the reserve. Thus, assessing whether we are protecting enough of our land base, in the right places, to capture a range of ecological values is only the first step in conserving ecosystems and biodiversity. Maintaining ecosystem processes and preventing species from going extinct requires attention to more than just the amount and location of protected areas (Noss 1995). The effectiveness of protection depends on the proximity to other protected areas, quality of the environment around the protected area, and the impact of internal and external stressors on the protected area.

ECOLOGICALLY INTACT MARINE AREA ON THE PACIFIC COAST

Humans use the ocean for many purposes, often directly affecting marine organisms and their habitats. A pilot project in 2006 (BCMOE 2006) obtained an estimate of ecologically intact marine areas, similar to the analysis for land, by defining intact marine areas as areas of more than 2,000 ha without human activities, aquaculture, bottom trawling and other fisheries, offshore seismic lines, oil and gas test drill sites, cruise ship routes, anchorages and moorage, boat launches, marine disposal sites, etc. Details of methodology and analysis are available in the BC Coastal Environment 2006 report (BCMOE 2006) (*www.env.gov.bc.ca/soe/bcce/*).

This analysis was a conservative attempt to quantify intact and affected marine areas because not all human activities in marine areas could be included. Nevertheless, they emphasize that only a small fraction—0.4% across the province—of the ecologically intact marine area is protected. Less than 25% of any continental shelf ecoregion (Georgia Basin, Inner Pacific Shelf, and Outer Pacific Shelf) could be classified as ecologically intact. The two deep-water ecoregions off of B.C.'s Pacific coast—the Transitional Pacific and Subarctic Pacific—were largely intact with respect to the activities included in that analysis, but had little or no protected areas.

8. Secondary Indicator: Changes in road intensity and road length in B.C.

Total road length and road density provides measures of the degree to which land has been affected by human activity. Roads have a detrimental effect on wildlife by fragmenting and altering their habitat, increasing roadkill, increasing access by people and predators, and by acting as a barrier to movement.

Methodology and Results

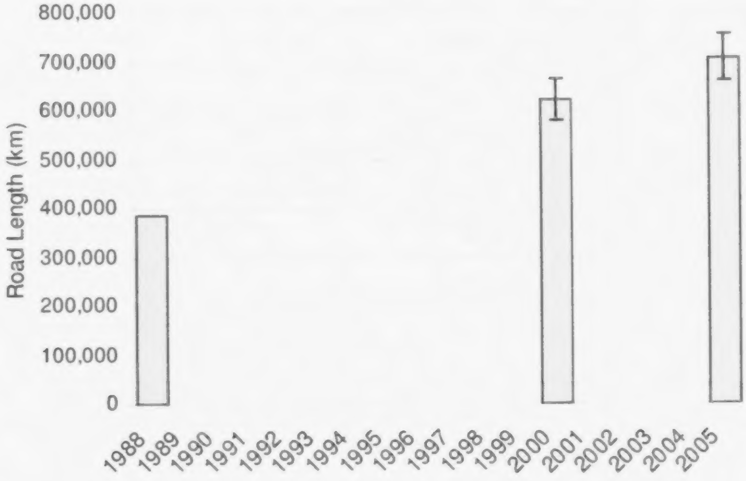
Road length data were obtained from National Forest Inventory photo plots, and analyses were conducted as described in Indicator 7 ("Proportion of ecologically intact land within protected areas"). Unlike the intactness indicator discussed above, this analysis does not include seismic lines. Road intensity is defined as the length of roads found in a given area of land, such as 2 km of roads per 1 km^2 of land. Two sets of road intensity data were produced: (1) the road intensity in each ecoprovince in 2005 and (2) the change in road intensity in the 5 years from 2000 to 2005.

Data are available for the entire land area of B.C. from the 1980s, 2000, and 2005. The 1980s data were derived from air photos of the province taken between 1981 and 1988. The data encompass all main and secondary roads, including paved, unpaved, and rough roads; Forest Service roads; and other forest and non-forest roads. The data set did not include seismic lines. Both the 2000 and 2005 estimates for road intensity were derived from the National Forest Inventory database, which uses a series of photo plots from across the province (for details of methods used, see Indicator 4 "Trend in the number of road crossings of streams"). The 2000 data included approximately 30,000 km of trails; no new trails were added to this figure for 2005.

In the 1980s, there were approximately 387,000 km of roads in B.C. (Figure 15). By 2000, road length had increased to 570,919 km, a 48% increase. In 2005, there were 702,574 km of roads, a 23% increase in just 5 years, and an 82% increase over the 1980s figure.

The road length data provide only a conservative estimate of the extent of habitat fragmentation in the province because seismic lines and new trails since 2000 have not been included.

Figure 15. Total length of roads in B.C. for 1998, 2000, and 2005.



Sources: 1988 data are from TRIM I air photos, 1981-1988. Integrated Land Management Bureau, Ministry of Agriculture and Lands. 2000, 2005: National Forest Inventory Photo Database. Analyzed by Forest Analysis and Inventory Branch, B.C. Ministry of Forests and Range.

Road intensity data show, not surprisingly, that the Georgia Depression has the most roads per area, at almost 3 km of roads per km^2 (Figure 16, Table 12). The Georgia Depression, which includes Greater Vancouver and southeastern Vancouver Island, also has the greatest proportion of the province's population. Road intensities of 1 to 2 km/km^2 occur in the Southern Interior, Boreal Plains, and Central Interior ecoprovinces. The remaining ecoprovinces have less than 1 km/km^2, with the Northern Boreal Mountains in the northwest of the province having the lowest intensity at 0.09 km/km^2. There are effectively no roads in the Southern Alaska Mountains ecoprovince.

In the five-years between 2000 and 2005 (Table 12):

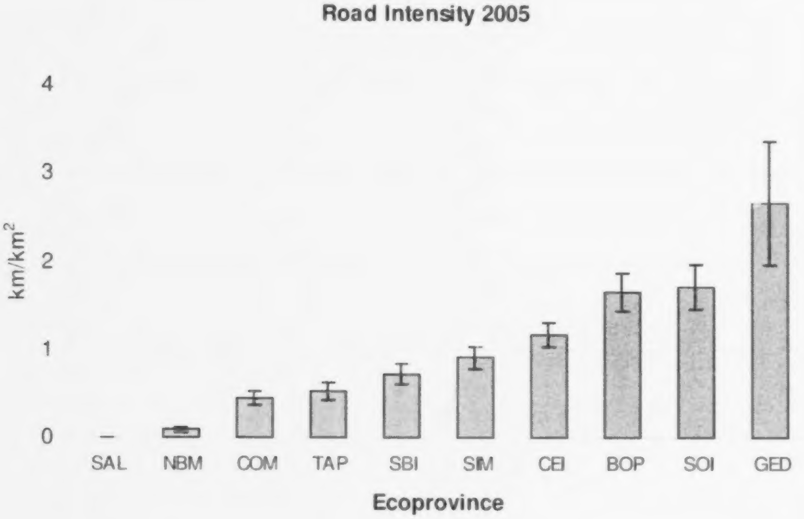
- The greatest increase in the length of roads occurred in the Central Interior (19,554 km of new roads).
- The least increase in road length was in the Georgia Depression (1,995 km of new roads).
- The greatest increase in road intensity occurred in the Boreal Plains (0.2315 km of new road built for every km^2).
- The least increase in road intensity was in the Northern Boreal Mountains (0.1461 km of new road built for every km^2).

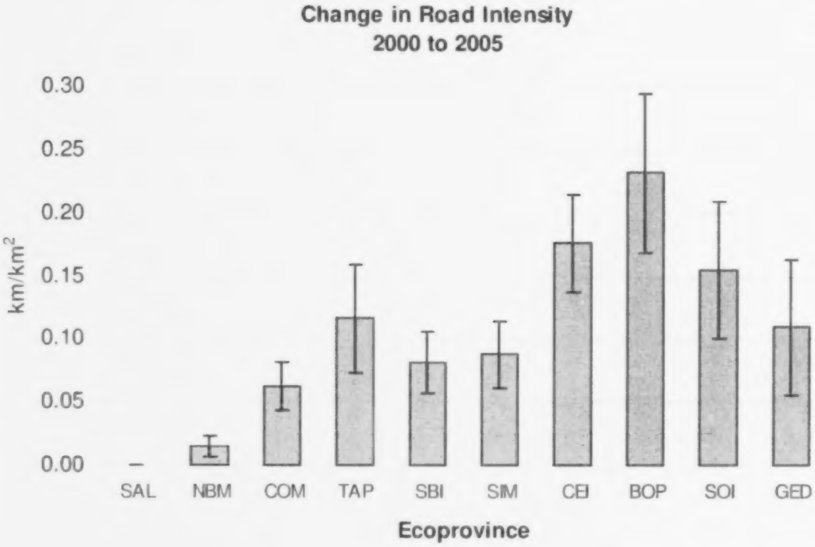
Table 12. Road length and intensity in B.C., by ecoprovince, in 2005 and the increase from 2000 to 2005.

Ecoprovince	Road length (km)		Road intensity (km/km^2)	
	Increase from 2000–2005	2005	Increase from 2000–2005	2005
Southern Alaska Mountains	–	–	0	0
Northern Boreal Mountains	2,761.00	17,066.34	0.01461	0.09030
Coast and Mountains	11,446.55	83,056.35	0.06255	0.45387
Taiga Plains	8,093.81	36,340.72	0.11613	0.52140
Sub-boreal Interior	11,287.04	100,997.86	0.08122	0.72680
Southern Interior Mountains	12,155.64	125,737.06	0.08807	0.91096
Central Interior	19,553.92	129,866.31	0.17599	1.16884
Boreal Plains	8,738.80	62,536.18	0.23152	1.65680
Southern Interior	8,864.89	98,219.65	0.15512	1.71871
Georgia Depression	1,995.29	48,754.00	0.10954	2.67646

Source: National Forest Inventory Photo Database. Analyzed by Forest Analysis and Inventory Branch, B.C. Ministry of Forests and Range.

Figure 16. Road intensity (km of road per km²) in B.C. by ecoprovince in 2005 (top) and increase in intensity from 2000 to 2005 (bottom).





Source: National Forest Inventory Photo Database. Analyzed by Forest Analysis and Inventory Branch, Ministry of Forests and Range.

Notes: Ecoprovinces are: NBM—Northern Boreal Mountains; COM—Coast and Mountains; TAP—Taiga Plains; SBI—Sub-boreal Interior; SIM—Southern Interior Mountains; CEI—Central Interior; BOP—Boreal Plains; SOI—Southern Interior; GED—Georgia Depression.

Supplementary Information: Road deactivation in B.C.

Many newly constructed roads in B.C. are access roads built by forest licensees to harvest timber. In addition to road construction, however, the forest industry is actively involved in road deactivation. Deactivation includes removing culverts, digging ditches or drains, changing the angle of the road surface, and breaking up the compacted road surface (Atkins et al. 2001). Road deactivation in B.C. began in the late 1980s because of concerns about landslides that were occurring where forest roads had been built on steep slopes (Dunkley et al. 2004). Landslides are a serious concern in mountainous areas, and the probability of landslides occurring is higher where forest roads have been built (Wise et al. 2004). A landslide has a 60% chance of causing environmental damage, according to a study conducted by the Forest Practices Board (2005).

In 1995, the Forest Practices Code (FPC) required forest licensees to have the stability of slopes assessed by a professional geologist and to include deactivation in the plans for a forest road. The Forest Practices Board (2005) evaluated roads that were built in three parts of the province (one interior and two coastal) and found that there had been fewer landslides, and landslides were less frequent near or in gullies and streams, than before the FPC had come into effect.

In 2004, the FPC was replaced by the *Forest and Range Practices Act* (FRPA). FRPA is a results-based approach in which the government sets objectives for licensees to manage and protect a variety of forest and range values, such as water quality, fish habitat and passage, wildlife habitat, and biodiversity. FRPA does not require landslide hazard mapping and assessments, but government objectives include avoiding negative effects from landslides on forest values (Fannin et al. 2007).

WHAT IS HAPPENING IN THE ENVIRONMENT?

Although barely 2% of the province's land area has been converted entirely to human uses such as urbanization and agriculture, human activities still have widespread effects on ecosystems.

Grasslands are highly disturbed and fragmented. They comprise less than 1% of the province's land area, yet support more than 30% of B.C.'s threatened and endangered species (GCCBC 2007). About 16% of the province's southern interior grasslands have been lost to agriculture and urbanization since the mid-1800s, with the greatest losses in the Okanagan. Domestic livestock grazing occurs in most (about 90%) of the remaining grasslands in B.C.

Up to one-third of B.C.'s forests have been disturbed by either logging or forest fires since the 1850s. These younger forests cover 12% of the coast and 36% of the interior land area. Interior forests experience a greater frequency of fires (about half caused by humans and half caused by lightning; BCMOFR 2007) and, since the 1970s, a greater amount of harvesting than the coastal forests (BCMOE 2006). Yet even lightning-caused wildfires are more intense due to half a century of fire suppression and subsequent build-up of fuels.

Human activities have had an enormous impact on Garry oak ecosystems. Most (90%) of the original Garry oak ecosystems on eastern Vancouver Island and the Gulf Islands have been lost.

The remaining fragments have been so degraded by introduced species that less than 5% of the original ecosystem remains in a near-natural condition.

Most development activities require roads. Where roads cross streams, improperly constructed culverts may disturb or destroy important fish and wildlife habitat. The highest number of roads and stream crossings is in the southern part of the province where 75% of the population lives, but the greatest increase since 2000 was in northeastern British Columbia, probably related to activities of the oil and gas sector in that area.

Estuaries amount to less than 3% of the province's coastline but are very important habitat for many species. More than a third of the intertidal area of 440 mapped estuaries have economic tenures that may have current or potential impacts on these important habitats. Fewer estuaries (28%) had conservation tenures to protect ecological values, but the total conservation area was more than three times the area under economic tenures.

Ecosystem protection is a vital part of maintaining wildlife habitats and ecosystem services. A protected area system:

- protects biodiversity and specific natural features
- contributes to human health and recreation
- contributes to the economy
- preserves wilderness.

B.C.'s protected areas cover 13.4% of the land area of the province, a higher percentage than the nation as a whole or any other province. The area of forest that is protected (9.7% in 2007) has more than doubled in the past 16 years, putting B.C. ahead of the nation as a whole in protecting its forests (Canada has 8% of its forests protected). Some ecosystems are not as well protected. Most of B.C.'s marine ecosections have less than 1% protected areas. Grasslands are biodiversity "hotspots" and are among Canada's most endangered ecosystems yet, in the case of southern interior grasslands, just 8% are protected.

Ecosystem protection is more than the establishment of a network of provincial protected areas. It must also address the effectiveness of protected areas. Maintaining connections within the landscape to other intact or undisturbed habitats and other populations (PEICNP 2000) is critical for protected areas to be effective. Human activity and infrastructure in the land between the province's protected areas threatens this connectivity.

Roads disrupt and fragment wildlife habitat, increase access for predators and poachers, and allow further industrial and urban development. Length of roads increased by more than 80% between the 1980s and 2005. About 31% of the land area in B.C. is intact or roadless (mostly at higher elevations), but only 8% of the province is both protected and intact. Connectivity may need to be restored in these disturbed environments if the protected areas within them are to maintain biodiversity and ecosystem function. Partnerships to acquire property adjacent to protected areas and to conserve areas that link protected areas into larger ecological corridors may now be more important than ever. In addition to securing land, there is also a need for private land stewardship by land owners in the working landscape of forestry and agriculture.

Human activities in the marine environment such as shipping, fishing, and tourism also affect ecosystems. Marine areas are not necessarily isolated in the same way as terrestrial areas, but they may still suffer from lack of connections to other protected areas. To protect bottom-dwelling marine species, this problem might be overcome by designating marine corridors (Carr et al. 2003).

What Effect is Climate Change Having on Ecosystems?

Numerous models have been developed to predict the changes in ecosystem composition, structure, and function at global and regional scales caused by climate change. The Intergovernmental Panel on Climate Change (IPCC 2001) identified two paradigms about the way ecosystems will respond to global change: (1) *ecosystem movement* assumes ecosystems will move to new locations that will be similar to their current climate and environment, and (2) *ecosystem modification* assumes that as the climate and environment change, new ecosystem types will develop that may be quite different from those we see today.

It is expected that in general B.C.'s ecosystems will experience upslope movement of treelines, northward migration of forests types in the interior, and expansion of grasslands northward and into higher elevations. Along with these generalized "ecosystem movements," climate change is likely to bring alterations in disturbance regimes (e.g., windthrow, fire, insect and disease outbreaks) and increased invasion of introduced species. The resulting modified ecosystems may well look different than B.C.'s current ecosystem composition. The complex relationships and habitats that now exist may collapse and be replaced by different ones. Species' abilities to move and adapt are variable and alien invasive species are usually more adaptable to changing conditions and can move faster than native species. Plant and animal species that are unable to adapt to the new conditions may become endangered or extinct.

B.C.'s protected area system is based on attaining representation of the diverse ecosystems that currently exist, but this may not adequately protect the new ecosystems that result from changing climate conditions. Protected area planning needs to consider climate change to ensure there is a healthy foundation for future ecosystems by preserving a diversity of geographical locations and landforms. It will be necessary to protect large, interconnected systems that allow for movement and evolution of populations and species to more suitable habitats as ecosystems change.

WHAT IS BEING DONE ABOUT IT?

People are beginning to seek a balance between the economic and social demands for our province's natural riches and the health of its ecosystems. Land managers are now looking at the more holistic approach of ecosystem-based management. In practical terms, ecosystem-based management means "establishing a comprehensive protected areas network within a well-managed working landscape" (The Nature Conservancy 2007).

Provincial Land Use Planning

Land use planning ensures that land is used efficiently for the benefit of the wider economy and population as well as protecting the environment. It is a vehicle for identifying, conserving, and protecting ecosystems in different regions of the province. Integrated land-use planning on Crown lands is the responsibility of the Integrated Land Management Bureau (ILMB) of the Ministry of Agriculture and Lands. According to the ILMB, more than 85% of the provincial Crown land base is now covered by 26 regional land use plans and land and resource management plans (LRMPs). Approximately 15% of B.C. remains without a regional land use plan or LRMP (e.g., Atlin-Taku, Nass, and Merritt Timber Supply Areas; ILMB 2006). The North and Central Coast LRMPs, which have nearly 30% of their combined area protected, are the first to adopt the Ecosystem Based Management process defined as "an adaptive approach to managing human activities that seeks to ensure the coexistence of health, fully functioning ecosystems, and human communities." For more information on provincial land use planning, see *ilmbwww.gov.bc.ca/lup*

The provincial government has some responsibility on private lands (e.g., provincial laws relating to forestry, water, wildlife), but local governments have considerable responsibility for managing land use on private land. Many local governments are applying smart growth principles to their regulatory tools, for example, regional growth strategies, official community plans, zoning bylaws, and development of standards and guidelines.

Federal Species at Risk Act (sararegistry.gc.ca)

The *Species at Risk Act* (SARA) provides protection for species at risk in Canada. Under the act, it is illegal to destroy or damage the residence, for example the nest or den, of a protected species. The act also contains prohibitions on other things, such as harming, selling or transporting individuals of a species at risk. The critical habitat of the species, which is necessary for their survival and recovery, can also be protected. Although SARA applies specifically to federal lands, it does have some provisions for making it an offence to destroy critical habitat of an endangered species when the habitat occurs on private or provincial lands (Environment Canada 2003).

Forestry Certification Programs

Beginning in the 1990s, third-party certification programs to identify and label forest products that originate in sustainably managed forests have been expanding. In Canada, at least four voluntary programs certify forests according to a set of environmental and social standards. These include:

- The Forest Stewardship Council
- The Sustainable Forestry Initiative
- The Canadian Standards Association
- The Program for the Endorsement of Forest Certification Schemes

More about forestry certification and the details of each certification system can be found at *www.metafore.org/index*.

Stewardship Partnership Initiatives

- **Stewardship Canada** is a partnership of federal, provincial, and environmental agencies that co-sponsor a website portal among other projects, have produced a set of practical guides on stewardship of different types of environments. For the Stewardship Centre for British Columbia information at this portal, see *www.stewardshipcentre.bc.ca/stewardshipcanada/home/scnBCIndex.asp*.
- **NatureScape BC** (*www.hctf.ca/naturescape*). NatureScape is a partnership of federal, provincial, and environmental agencies aimed at restoring, preserving, and enhancing wildlife habitat on private land in urban and rural landscapes throughout the province.

NGO Initiatives

Conservation initiatives by the provincial and federal governments are complemented and enhanced by non-governmental organizations that play a significant role in ecosystem protection:

- **BC Trust for Public Lands** The Trust, delivered through the BC Conservation Lands Forum, is a partnership between government and the conservation sector to secure and manage ecologically sensitive lands and to plan for biodiversity. (*www2.news.gov.bc.ca/nrm_news_releases/2004SRM0036-000815.htm*)
- **Biodiversity BC** is a partnership of conservation and government organizations formed in 2005 to develop a biodiversity action plan for British Columbia. (*www.biodiversitybc.org/EN/index.html*)
- **BirdLife International** Nature Canada and Bird Studies Canada work as Canadian partners with BirdLife International to designate Important Bird Areas (IBA) to protect and monitor a network of vital habitats for conserving bird populations and biodiversity around the world. (*www.naturalists.bc.ca/projects/iba/iba_intro.htm*)
- **Canadian Parks and Wilderness Society** CPAWS is a non-profit conservation organization, promoting the establishment of new protected areas and management of existing parks. (*cpawsbc.org*)
- **Grasslands Conservation Council of British Columbia** The GCC is an alliance of organizations and individuals committed to education, conservation and stewardship of B.C.'s grasslands. (*www.bcgrasslands.org*)
- **Habitat Conservation Trust Fund** HCTF funds projects that acquire, protect, restore, or enhance fish and wildlife habitat. (*hctf.ca*)
- **Wildlife Habitat Canada** WHC promotes and funds conservation, restoration and enhancement of wildlife habitat in Canada. (*whc.org*)
- **World Wildlife Fund Canada** WWF works to conserve species at risk, protect threatened habitats and address global threats. (*wwf.ca*)

Land Trusts

Land trusts or conservancies are non-profit, charitable organizations dedicated to the protection of natural and/or culturally significant lands. They frequently work in partnership with governments, other organizations, foundations, and businesses to achieve shared conservation goals. A land trust may own land itself, or it may enter into conservation covenants with property owners to protect or restore natural or heritage features on the owner's land. There are more than 32 local land trusts in B.C. A list of these, with contact information, is available from The Land Trust Alliance of B.C., an umbrella organization that provides support to land trusts and conservancies and to other organizations and individuals. (*www.landtrustalliance.bc.ca*)

The larger trusts include:

- **The Nature Trust of British Columbia** (*naturetrust.bc.ca*). The Nature Trust acquires and manages areas of ecological significance in the province.
- The Land Conservancy of British Columbia (*conservancy.bc.ca*). TLC protects important habitat for plants, animals, and natural communities.
- **The Nature Conservancy of Canada** (*natureconservancy.ca*). NCC partners with corporate and individual landowners to protect ecologically significant land nationwide through land donation, purchase, and conservation easement, as well as by securing mineral rights and timber rights on properties.
- **Ducks Unlimited** (*ducks.ca*). DU conserves, restores, and manages wetlands and associated habitats for North America's waterfowl.

WHAT CAN YOU DO?

Practice good environmental stewardship on your land or property.

- Stewardship Centre for British Columbia publishes *The Stewardship Series* that provides guidance on developing more sustainable communities by protecting and enhancing natural ecosystems: *http://dev.stewardshipcanada.ca/sc_bc/stew_series/NSCbc_stewseries.asp?sProv=bc&siteLoc=scnBC&lang=en.*
- Reduce your ecological footprint by making responsible choices in your daily use of transportation, food, goods, and energy.
- Support "green businesses" that reduce their ecological footprint, use product certification, and construct green buildings to reduce impacts on ecosystems.
- Support and encourage efforts at your workplace toward sustainable business practices.
- Join a local conservation organization and volunteer time to help them protect, conserve, or restore wild species and ecosystems.
- Donate money or land to a land trust. Several established trusts operate nationally, provincially, or locally.

- Create a conservation covenant with a land trust or government through Environment Canada's Ecological Gifts Program (landowners are eligible for benefits such as tax credits and reduced capital gains under Canada's *Income Tax Act*). For information, see *www.cws-scf.ec.gc.ca/ecogifts/intro_e.cfm*.

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Species Conservation

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Species Conservation

BACKGROUND

British Columbia occupies 10% of Canada's land area but contains more than half of Canada's species of vertebrates and vascular plants and three-quarters of the country's bird and mammal species (BCMELP and EC 1993). The complex glacial history, extensive coastline, mountain chains, and grasslands make British Columbia one of the most biologically diverse provinces in Canada. The province's remaining old-growth coastal rainforests are exceptionally rich in biological diversity and represent approximately one-quarter of all remaining coastal temperate rainforests worldwide (BCMOF 2004). The southern interior grasslands contain a large proportion of B.C.'s endangered and threatened species, and the province's estuaries and wetlands support a wide variety of species, including more than 300 species of birds (BCMSRM 2004b; BCMOE 2006b).

Some species that were once widespread elsewhere still have a last refuge in the steep and inaccessible terrain in parts of the province. The province is one of the last places left with a complex of large predator–prey systems (Laliberte and Ripple 2004). It has some of the last freshwater ecosystems naturally without fish, which are important for conserving amphibian and invertebrate species.

British Columbia is home to 142 mammal, 488 bird, 468 fish, 22 amphibian, and 18 reptile species (BCMELP and BCMOE 1999). Invertebrate species are estimated to number 50,000 to 70,000, of which about 35,000 are insects. The province is also home to about 2,800 species of vascular plants, 1,000 species of mosses and liverworts, 1,600 species of lichens, 522 species of attached algae, and over 10,000 species of fungi. Many of these species are endemic (meaning locally unique and native) to the province. For example, 24 of B.C.'s mammals are found nowhere else in Canada, and 162 of B.C.'s bird species breed only in the province (BCMELP and BCMOF 1999).

As many as 44 species in B.C. are considered "imperilled" or "critically imperilled" on a global scale (terms used by the global organization *NatureServe* for species ranking) (CDC 2005). This means that the province bears a share of the global responsibility for conserving them. Examples include the Oregon spotted frog (*Rana pretiosa*), an aquatic native of the Fraser Valley; the Cowichan lake lamprey (*Lampetra macrostoma*), a fish found in only two lakes on Vancouver Island; the caribou rams-horn (*Planorbella columbiensis*), a mollusc recorded only in Lac La Hache in the central interior; Gillette's checkerspot (*Euphydryas gillettii*), a butterfly restricted to localized areas in the southeastern corner of B.C. along the Rocky Mountains; and Keen's long-eared myotis (*Myotis keenii*), a small bat that occurs in humid forests from Alaska to Washington.

TAXONOMIC NOTE

For all discussions in this paper, the term "species" includes the full scope of species, subspecies, and significant populations (i.e., taxa) that are the focus of conservation listing in British Columbia and Canada.

How Conservation Status is Ranked in B.C.

Several key organizations provide species conservation information in British Columbia. At the national level, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) is an independent body of experts who use scientific, aboriginal, and community knowledge to categorize species according to conservation risk. Species at risk are those that have been extirpated (meaning extinct in a local area, province, or country) or are designated as endangered, threatened, or of special concern (see text box "Ranking Species At Risk in British Columbia"). As of June 2005, COSEWIC had assessed more than 500 plant and animal species as being at risk in Canada, meaning that their continued existence in this country is in danger. About 180 of those species occur in British Columbia. Seven that once occurred in B.C. are now extinct or extirpated in Canada: the Island marble butterfly (*Euchloe ausonide insulanus*), Puget Oregonian snail (*Cryptomastix devia*), Pacific gophersnake (*Pituophis catenifer catenifer*), Pacific pond turtle (*Actinemys marmorata*), pigmy short-horned lizard (*Phrynosoma douglasii*), a subspecies of the Greater Sage-grouse (*Centrocercus urophasianus phaios*), and a subspecies of caribou (*Rangifer tarandrus dawnsonii*).

Within British Columbia, ranking of the conservation status of species is based on a standard set of criteria developed over the past 25 years by the international organization *NatureServe*. This is an international organization of cooperating conservation data centres and natural heritage programs, all using the same methodology to gather and exchange information. With guidance from various experts in North America, *NatureServe* scientists assign each species a global rank and a national rank. A species is also assigned subnational ranks, or "S-ranks," based on the status of species within each province or state in its range. The British Columbia Conservation Data Centre (CDC), in the Ministry of Environment, is the government body responsible for assigning the provincial S-ranks.

The CDC also publishes annually the provincial Red, Blue, and Yellow lists of species that have been assessed by provincial biologists (see text box for definitions of lists). As of February 2007, the Red list (species most at risk) contained 490 organisms and the Blue list, 513 organisms. So far, assessed groups in B.C. include mammals, birds, amphibians, reptiles, freshwater fishes, freshwater molluscs, butterflies, dragonflies, vascular plants, and mosses. Species legally designated as Extirpated, Endangered, or Threatened under the B.C. *Wildlife Act* are included on the provincial lists. As of May 2007, the sea otter (*Enhydra lutris*) was legally designated as Threatened; American White Pelican (*Pelecanus erythrorhyncos*), Burrowing Owl (*Athene cunicularia*), and Vancouver Island marmot (*Marmota vancouverensis*) were designated as Endangered.

Ranking Species at Risk in British Columbia

Terminology used by different conservation classification systems can be confusing. This table shows equivalent designations for species considered "at risk" of extinction and those "not at risk" according to the classification systems referred to in this paper.

Risk Level	BC CDC S-ranks[1]	Provincial Lists[2]	COSEWIC Categories[3]
At risk	SX Extinct/extirpated	Red List	Extinct
	SH Historic		Extirpated
	S1 Critically imperilled		Endangered
	S2 Imperilled		Threatened
	S3 Special concern	Blue List	Special Concern
Not at risk	S4 Apparently secure	Yellow List	Not at risk
	S5 Secure		

[1] **BC Conservation Data Centre Subnational ranks (S-ranks).** S-ranks are based on many factors, including number and viability of existing occurrences, trends in population size and geographic distribution, and threats facing the species or its habitat.

[2] **Provincial lists:** The BC Conservation Data Centre uses S-ranks to assign species to one of three provincial lists:

- Red list: Extirpated or presumed extirpated (not reported for 20–40 years). Species legally designated as threatened or endangered under the provincial *Wildlife Act* and all candidates for such designation (the majority of Red-listed species). Includes compound S-ranks: S1S2 and S1S3.
- Blue list: Species not immediately threatened but of concern because of characteristics that make them particularly sensitive to human activities or natural events. Includes compound S-ranks: S2S3 and S3S4 (animals only).
- Yellow list: all species not on the Red or Blue lists, but tracked by the CDC; they are not considered to be at risk.

[3] **Committee on the Status of Endangered Wildlife in Canada.** Species assessed by COSEWIC are designated as:

- Extinct: No longer exists.
- Extirpated: No longer exists in the wild in Canada, but occurs elsewhere.
- Endangered: Facing imminent extirpation or extinction.
- Threatened: Expected to become endangered if limiting factors are not reversed.
- Special concern: May become threatened or endangered for a combination of reasons.
- Not at Risk: Evaluated and found to be not currently at risk of extinction.

Species for which there is inadequate information to make an assessment are designated as "Data deficient."

As a signatory to the national 1996 Accord for the Protection of Species at Risk, British Columbia committed to supporting the recovery of threatened and endangered species in the province. Until the federal *Species at Risk Act* (SARA) was proclaimed in June 2003, however, no legislation specifically protected Canadian species at risk. SARA has three goals: (i) to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extinct or extirpated (locally extinct); (ii) to provide for the recovery of endangered or threatened species; and (iii) to encourage the management of other species to prevent them from becoming at risk. To list a species under SARA, COSEWIC recommends it to the Minister of Environment based on a status assessment. After a period of public consultation, the federal Cabinet considers the recommendation, taking into account social, political, and economic factors, and decides whether the species should be added to the legal list of species at risk (Environment Canada 2005). SARA requires that a recovery strategy and an action plan be prepared for any extirpated, endangered, or threatened species listed under the act. Management plans are necessary for species of special concern. The federal minister is required to report on the progress of implementing each strategy and plan.

This paper focuses on indicators related to the conservation status of species (including populations, subspecies, and species groups) in British Columbia. In so far as the indicators show trends in species richness and abundance, they are also indicators of some aspects of biodiversity in the province. Biodiversity (biological diversity) is the abundance, variety, and interdependence of living organisms on the planet, including their genetic variety and the complex of natural communities and ecosystems of which they are part. The status and health of ecosystems and natural habitat in the province, which are also indicators of biodiversity, are discussed in the "Ecosystems" paper of this report, "Environmental Trends in British Columbia: 2007."

INDICATORS

1. Key Indicator: Changes in the conservation status of fauna and flora in B.C.

This is a state or condition indicator. It addresses the question: What is the overall change in status of large groups of species?

Conservation status of species, usually summarized as the proportion of native species that are at risk, is widely used as the basis for tracking trends in biodiversity (e.g., Environment Canada 2003; IUCN 2003b). Despite widespread use, however, indicators that summarize conservation status have been criticized because changes in knowledge of a species or how its status is assessed can mask actual changes in the status of the species (Possingham et al. 2002; Keith and Burgman 2004).

The conservation status of a species may change as a result of changes in one or more of the following:

- Organism taxonomy (e.g., single species are "split" into multiple species, or multiple species are "lumped" into one);
- Methods for assessing risk or assigning risk categories (e.g., the procedure for assessing status is changed);
- Knowledge of a species' status (e.g., new information about a species may show that it is at greater or lesser risk than had been previously assumed);
- Actual species status (e.g., the real abundance or distribution of a species has changed).

It is commonly assumed that a change in conservation status reflects a real change in the species status. However, a recent study of threatened and endangered vertebrate species in B.C. showed that 65% of the changes in status reported over 10 years were a result of increased knowledge or changes in assessment methods or taxonomy (Quayle and Ramsay 2005). The same study also found that some of the province's threatened and endangered species are naturally rare and that even in a pristine landscape they would likely never be ranked "Secure" (see text box).

To address these shortcomings, the following indicator was developed to correct for changes in taxonomy, assessment, and knowledge. The indicator improves on previous indicators by listing only the genuine change in the status of a species. It does not yet represent all species groups in B.C., but reptiles, amphibians, and some groupings of plants and invertebrates will be included in future.

Methodology and Data

The British Columbia Conservation Data Centre (CDC) publishes the provincial lists of species considered by provincial biologists to be endangered or threatened (Red list), of conservation concern (Blue list), or secure (Yellow list). The CDC is a member of NatureServe, which is an international organization of cooperating conservation data centres. There are 8 Canadian and 50 American local member programs that make up the NatureServe network in North America (NatureServe 2006). These centres all use the same methodology to gather and exchange information on threatened species.

Since 1992, BC CDC has assigned "S-ranks" (subnational or provincial status ranks) to the province's species based on a standard set of criteria (Master 1991; Regan et al. 2004). The S-ranks represent the level of extinction risk for each species within the province (see text box "Ranking Species at Risk in British Columbia").

For this indicator, changes in provincial S-ranks were determined by a method described in Quayle et al. (2007), who adapted the methods used for a global analysis (see Butchart et al. 2004; 2007). S-ranks for species were retrospectively corrected to adjust ranks that had over- or underestimated actual changes. Using their current knowledge of species ranking, biologists who assigned past ranks were asked to review rankings for 1992, 1997, and 2001. They were asked to distinguish real changes in status from changes due to other factors, such as increased knowledge or changes in assessment methods or taxonomy. Reviewers also checked S-ranks for species where no change had been recorded between 1992 and 2001 to look for real change that may not have been detected at the time.

The analyses in this indicator focussed on S-rank data for species within their natural range and breeding regularly in British Columbia between 1992 and 2007. Species ranked as historic (not observed for 40 years) or extirpated before 1992 were removed from the data set. Nonbreeding species, such as transient birds, were generally excluded from the data to ensure that the indicator reflected only species that rely on the province for at least one significant stage in their life cycle.

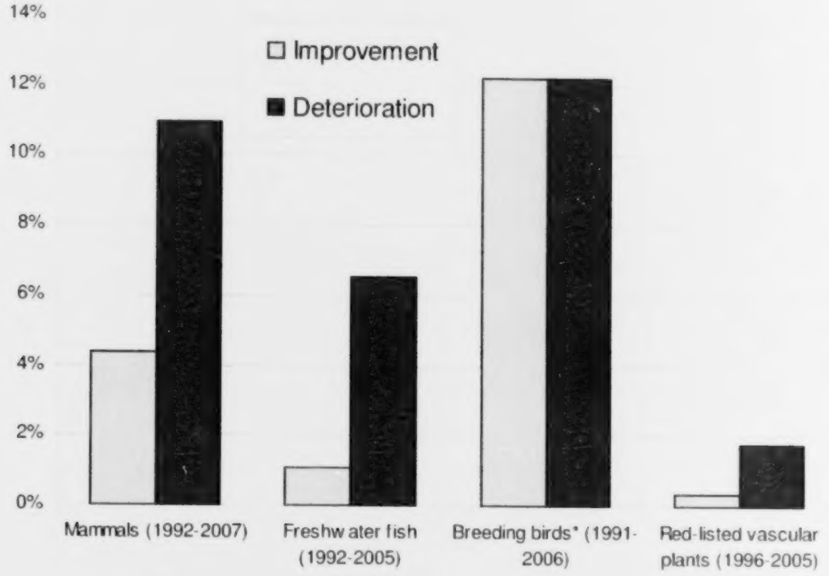
In cases of uncertainty, the NatureServe methodology used by the CDC allows a species to be assigned a compound rank (e.g., S1S2) to represent a range of possible S-ranks (NatureServe 2006). For such cases, the more precautionary of the two S-ranks was used in the analysis for the indicator. For species (mainly birds) that had different ranks assigned to the breeding and nonbreeding components of their life cycle, the rank of the breeding component was used in the analysis.

Although this indicator provides a more accurate picture of real change in species status than indicators based on simple proportions of species listed, there are two main limitations to this analysis.

1. It effectively sets an artificial, and relatively recent, baseline in 1992. This problem is most notable for three species extinct by 1992 that were not factored into the analysis: Dawson caribou (*Rangifer tarandus dawsoni*), Dragon Lake whitefish (*Coregonus* sp. 1), and Passenger Pigeon (*Ectopistes migratorius*). It also means that species on the "rebound" from decreased hunting, for example, can show as improving status. Such species could have had much larger populations before 1992. Improvement in the population status after 1992 may be small or negligible compared with the historic status. In future, of course, this baseline date will be less of a problem as species continue to tracked.

2. S-ranks are relatively crude measures of status. They allow for considerable change in population, distribution, and vulnerability before a species crosses the threshold that requires it to be assigned to a new status (c.f., killer whale ecotypes on the B.C. coast). For species already ranked at the lowest status (S1, Critically Imperilled), the next threshold they will cross if their numbers do not improve is to extirpation. A lack of change for S1 species may create the impression of stability in this indicator, whereas "Critically Imperilled" species are typically not characterized as stable. For example, the Spotted Owl (*Strix occidentalis*) has been ranked as S1 since its initial evaluation in 1992, which means that in the analysis it is categorized as Stable. Yet, over the period 1992–2007, the Spotted Owl population has been rapidly declining (CDC 2007).

Figure 1. Proportion of species in B.C., by species group, whose status improved or deteriorated enough to change the conservation status.



Sources: Breeding birds data from Quayle et al. 2007. Original data for other groups from BC Conservation Data Centre, accessed September 2005 (vascular plants), September 2006 (freshwater fishes), January 2007 (mammals). Data analyzed according to methods outlined in Quayle et al. 2007.

* Breeding birds include new immigrant species.

With the exception of breeding birds, over the period analyzed for each species group, more species were found to have deteriorated in conservation status than improved (Figure 1). More than 10% of mammal and breeding bird species deteriorated, whereas just over 6% of freshwater fish and nearly 2% of vascular plant species deteriorated. Breeding birds had the largest improvement at 12%. One-third of these improving bird species were new immigrants, having arrived in B.C. since 1947.

Details for each species group, including changes over time, are given below.

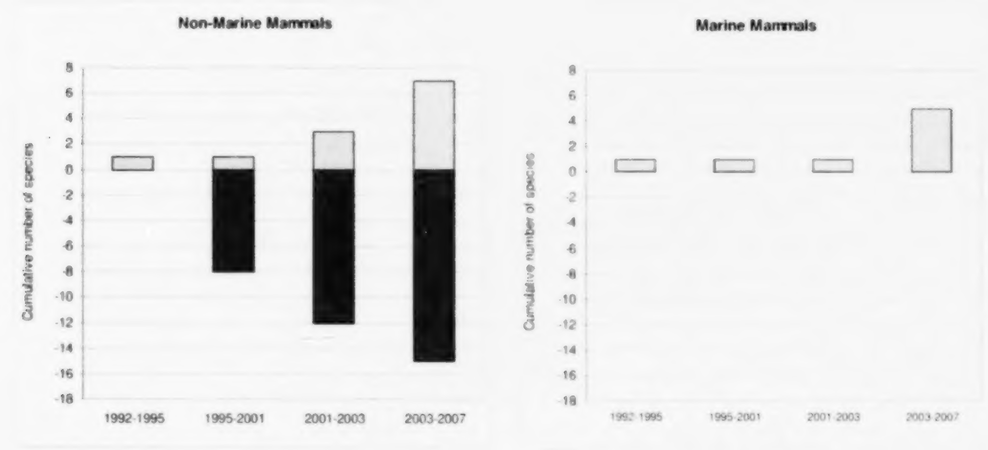
Figure 2 shows the cumulative number of mammal species that moved up or down at least one status category in specific time periods. Figure 3 shows the cumulative number of bird species that changed category. For the cumulative graphs, it is important to note that the species that changed status in one time period are then carried forward and added to the species for the next time period. For example, if three species improved in the first time period and two improved in the second period, the first bar shows three species and the second bar shows five species. Also, some species may have been counted more than once if they changed status in two or more of the time periods. For all time periods where the bars above the zero line are smaller than the bars below the line, the overall extinction risk is increasing. The design of the graphs was adapted from Baillie et al. (in press).

Mammals

Marine mammals included in the analysis were those for which S ranks were available. These species were known to breed in B.C. (e.g., northern sea lions, sea otters, harbour porpoises), or suspected to breed in B.C., such as sperm whales (c.f., Gregr and Trites 2001). Humpback and grey whales were also included, although they do not breed in B.C., because they forage with calves in tow in British Columbia waters and this is a critical part of their life cycle.

Of the 137 mammals analyzed, 78 species (57%) were considered Apparently Secure or Secure (S4, S4S5, or S5) for the entire period of analysis. However, the analysis shows an overall deterioration in the status of B.C.'s nonmarine mammal species (Figure 2). Although the S-ranks of some nonmarine species have improved, more have deteriorated. The status of all marine mammal species either remained unchanged or improved (Figure 2).

Figure 2. Cumulative number of nonmarine (left) and marine (right) mammal species that changed status by at least one category (S-rank) in B.C. since 1992 (*n* = 122 nonmarine species, *n* = 15 marine species). Light bar = improving (higher) S-rank; dark bar = deteriorating (lower) S-rank.



Source: Original data from BC CDC, accessed January 2007. Data analyzed according to methods outlined in Quayle et al. 2007.

The deteriorating status of many nonmarine mammal species results, at least in part, from the alteration and loss of their habitat. Mammals with large ranges are particularly vulnerable to changes that fragment their habitat because fragmentation reduces their ability to range widely for activities such as migration or escaping predators. Species with large home ranges and that have deteriorating status because of habitat alteration and loss include the Vancouver Island subspecies of wolverine (*Gulo gulo vancouverensis*) (COSEWIC 2003d) and three ecotypes of woodland caribou (*Rangifer tarandus caribou*) (COSEWIC 2002).

The improving status of marine mammals correlates with the impacts of policy decisions to protect several species: northern sea lions (*Eumetopias jubatus*), sea otters (*Enhydra lutris*), grey whales (*Eschrichtius robustus*), humpback whales (*Physeter macrocephalus*), and sperm whales (*Megaptera novaeangliae*) (COSEWIC 2003a,b, 2004). Since 1970, sea lions have been protected by regulations under the federal *Fisheries Act*. The improved status of sea otters follows their reintroduction to the B.C. coast between 1969 and 1972 (more information in BCMOE 2006a). In 2007 COSEWIC moved the sea otter from Threatened to Special Concern. The improved status of large whales correlates with their recovery from low numbers after an international ban on whaling imposed in 1986 and a ban on driftnet fishing in 1992.

The fact that the S-ranks of marine mammals have not deteriorated since 1992 appears to conflict with recent designations of transient and southern resident killer whales (*Orcinus orca* ecotypes) as endangered species in both the US and Canada. However, this apparent contradiction is explained by the retrospective method used for this indicator, which allows past ranks to be corrected or assigned in light of current knowledge. Before 2001, only one killer whale ecotype had been ranked in British Columbia, but the analysis for this indicator provides the hindsight to suggest that the true status of some killer whale ecotypes had already deteriorated before then. Based on what is currently known about killer whale ecotypes in the Pacific Ocean, transient and southern resident killer whales were retrospectively ranked as S2 (Imperiled) back to 1992. Northern resident killer whales were assigned a rank of S3 (Special Concern) retrospectively to 1992. Therefore, over the period of this analysis (1992–2007), the declining status of these three killer whale ecotypes has remained within the range of their adjusted rank (see Quayle and Ramsay 2005 for a discussion of this as an issue when using Conservation status ranks as indicators).

Breeding Birds

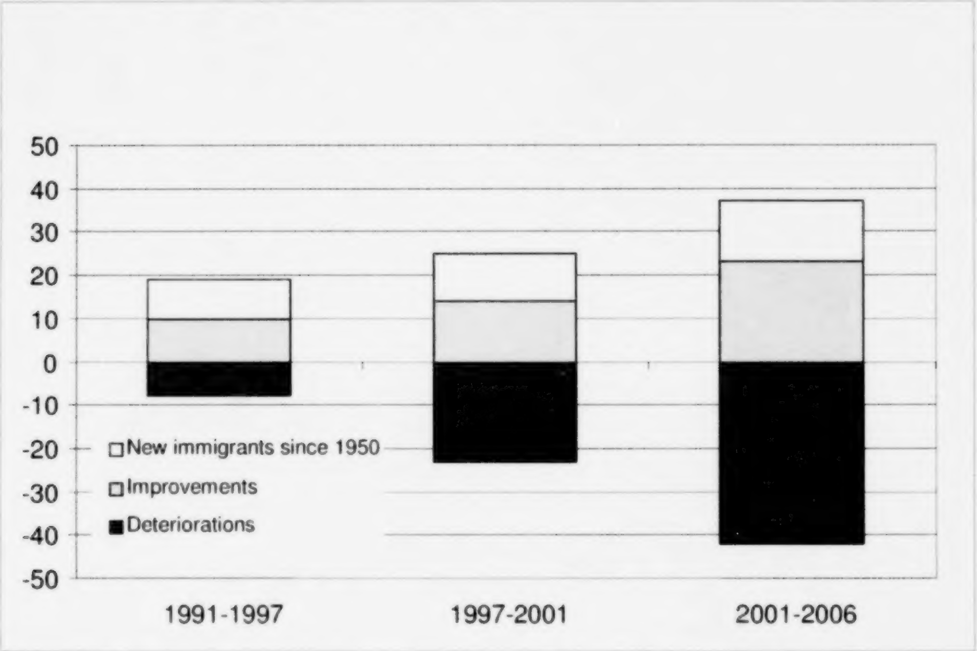
The 303 bird species known to breed in the province were included in the analysis. Species that regularly or sporadically occur in B.C., but for which there is no record of breeding in the province, were not included.

The analysis of bird data differed from the other groups because new immigrant breeding species were analyzed separately. New immigrants are species that have arrived in B.C. of their own accord and are believed to have become established in the province since 1947 when the first provincial bird species list was published (McTaggart-Cowan et al. 2001). Since 1947, 25 new immigrant species, including the Blue Jay (*Cyanocitta cristata*), Anna's Hummingbird (*Calypte anna*), and Ring-billed Gull (*Larus delawarensis*), have become established in British Columbia. They began by colonizing small areas of the province and their numbers and distribution then increased over time. Because the improving S-ranks for these species reflect this colonization, they were analyzed separately from other resident species.

Most breeding bird species (70–75% of species depending on the time period) were assigned S-ranks of Apparently Secure or Secure (S4, S4S5, or S5). The overall trend in bird conservation status shows deterioration (Figure 3), but the degree depends on whether new immigrant species (shown as the light coloured bars on Figure 3) are considered. If they are included, the number of species with deteriorating status exceeded the number with improving status only in the 2001–2006 period. If new immigrant species are not included, the number of species with deteriorating status was higher than the number improving in the two most recent time periods, 1997–2001 and 2001–2006.

Over the periods analyzed, one breeding bird became extirpated: a subspecies of Horned Lark (*Eremophila alpestris strigata*) was ranked as S1 (Critically Imperilled) in 1992 and eventually designated SX (Extirpated) in 2006.

Figure 3. Cumulative number of indigenous breeding bird species that changed status by at least one category (S-rank) in B.C. since 1992 (*n* = 303 species). Dark bars = deteriorating (lower) S-rank; middle bars (species present before 1947) and lightest bars (species immigrating since 1947) = improving (higher) S-rank.



Source: Quayle et al. 2007.

Freshwater Fishes

The freshwater fishes analyzed included those that spend their entire life cycle in freshwater (resident fish such as sculpins, dace, and bull trout), as well as those that spend only part of their life cycle in freshwater (anadromous fish such as salmonids and eulachon).

For freshwater fishes, 42 of 92 species (46%) were ranked as Apparently Secure or Secure (S4, S4S5, S5) for all three time periods analyzed. Between 1992 and 1998, six species deteriorated and only one improved. The analysis shows no net change since that period.

Only one species improved its status, the Lower Fraser population of white sturgeon (*Acipenser transmontanus*). Although they appear to be recovering, their numbers are still well below historic levels (Walters et al. 2005).

The six deteriorating species include the once-common eulachon (*Thaleichthys pacificus*). Since 1990, eulachon have declined coast-wide to the point that they are no longer available for traditional harvest in much of the historic range. Hay (1999) listed numerous threats contributing to the decline of eulachon, including over-harvesting and loss as by-catch in trawl fisheries; spawning failures due to disturbance; degraded water quality from urban land development and coastal forest practices; industrial activity and dredging; and increasing water temperatures.

Other deteriorating species are Pacific lamprey (*Lampetra tridentata*), coho salmon (*Oncorhynchus kisutch*), sockeye salmon (*O. nerka*), and two now extinct species, the Hadley Lake limnetic and benthic sticklebacks (*Gasterosteus* sp. 12 and sp. 13).

Although the indicator shows that little has changed, it does not mean that the status of freshwater fish is stable. Freshwater fish are particularly vulnerable to change in their local environment because of their limited ability to disperse. Many freshwater fish species in B.C. have very restricted distributions (Cannings and Ptolemy 1998), which puts them at risk of extinction from local events. For example, two species of Hadley Lake sticklebacks became extinct when non-native catfish, which prey on stickleback eggs, were introduced to the only lake in which they occurred (on Lasqueti Island).

Red-listed Vascular Plants

The S-ranks of vascular plants were checked in the same way as for the vertebrates, except that only Red-listed plants were included in the analysis and only one time period (1996–2005) was used. Over this time, the S-rank changed for 82 Red-listed species, 46 of which were removed from the Red list. Much of this change was the result of new knowledge, improvements in plant taxonomy, and refinement in how the conservation status of plants is determined. Eighty-three new species were also added to the Red list during the 1996–2005 time period, for a net increase of 37 species of vascular plants.

After checking the reasons for the change in S-rank for each plant species, it was found that only seven species showed a genuine improvement or deterioration in status. A single species improved in status: the pink sand-verbena (*Abronia umbellata* ssp. *breviflora*) changed status from SX (Extirpated) to S1 (Critically Imperilled). The status of six other plant species deteriorated: deltoid balsamroot (*Balsamorhiza deltoidea*), dense spike-primrose (*Epilobium densiflorum*), brook spike-primrose (*Epilobium torreyi*), white meconella (*Meconella oregano*), coast microseris (*Microseris bigelovii*), and rosy owl-clover (*Orthocarpus bracteosus*).

Interpretation

This indicator shows that the S-rank of the majority of animal species analyzed did not change between 1992 and the mid-2000s (2005 for freshwater fish, 2006 for breeding birds, and 2007 for mammals). For those species that changed status in this time period, more species deteriorated than improved. The same was true of Red-listed vascular plants between 1996 and 2005.

The species with an improving rank tended to be one of the following:

- An immigrating species expanding its distribution in the province, as is the case for many birds.
- A rebounding species, such as marine mammals, with a population recovering from historically low numbers because conservation measures have been put in place to protect it.

The indicator does not appear to show a positive effect that could be attributed to the 1996 federal Accord for the Protection of Species at Risk. Population recovery is a slow process, particularly for the vertebrates that produce only a few young each year. In contrast to species that have rebounded relatively rapidly because they are now protected from being killed, it is likely that the period covered by this indicator is not long enough to show recovery of species that have declined because of impacts to their habitat. Changes made to the way habitats are altered by forestry practices and other human activities, for example, may take much longer to bring about improvements in the status of species that use those habitats

Long-term research shows that the total number of breeding bird species has been increasing in British Columbia since 1890 (McTaggart-Cowan et al. 2001). The establishment and spread of immigrant species raises a question of whether tracking overall changes in the status of species can be seen as a sign of an improvement in biodiversity. The BC CDC assigns S-ranks to species based exclusively on the status of populations for which British Columbia has responsibility, regardless of the status of the species in neighbouring jurisdictions. As a result, species on the edges of their range in the province can change rank over the study period as a result of natural movements in and out of the boundaries of the province. This is the case for many of the new immigrant bird species, which show an improvement in S-rank as they spill into British Columbia from neighbouring jurisdictions and as their population expands in the province. They may replace species with dwindling numbers, or possibly through competitive exclusion, may expand their range by taking over another species' ecological niche (e.g., Paine 1974). Many species expanding their range in the province are well adapted to human modified landscapes (e.g., House Finch, Bushtit, Blue Jay, Common Grackle, Anna's Hummingbird, several species of gulls).

Global climate change is also expected to lead to latitudinal shifts in species ranges (Thomas et al. 2004), a phenomenon already documented for birds in British Columbia (Bunnell and Squires 2005). If climate change leads to more immigration of southern species to British Columbia, this indicator could actually show further improvement in the status of bird fauna in the province, even though this "improvement" would be a result of the impact of climate changed by human activities. Plant species (discussed in Indicator 5), may also respond to a changing climate by expanding their ranges from outside British Columbia.

2. Secondary Indicator: Percentage of known species and ecological communities on the B.C. Red list

This is a state or condition indicator. It addresses the question: How many of B.C.'s known species and ecological communities are at greatest risk of extinction?

Threatened or endangered species and ecological communities are those that are at the greatest risk of declining and ultimately becoming extirpated (locally extinct) or extinct. These species and ecological communities are included on B.C.'s Red list (for definition, see the text box "Ranking Species at Risk in BC"). The Red list includes extirpated species; to date no ecological communities have been recorded as extirpated.

The proportion of species at risk in B.C. is a measure of the current status of one aspect of biodiversity, consistent with other reporting in Canada and internationally (Environment Canada 2003; IUCN 2003b). As discussed in the introduction to Indicator 1, however, this measure has shortcomings as an indicator of trends in biodiversity. This is due to the large effect that changes in taxonomy, assessment methods and the state of knowledge of particular species have on status rankings (c.f., Quayle and Ramsay 2005).

Five species are extinct in B.C. and are not counted in this indicator. They are two stickleback species that were found in a single lake on Lasqueti Island (the Hadley Lake limnetic and benthic sticklebacks); Dragon Lake whitefish, also from a single lake; Passenger Pigeons; and Dawson caribou.

Methodology and Data

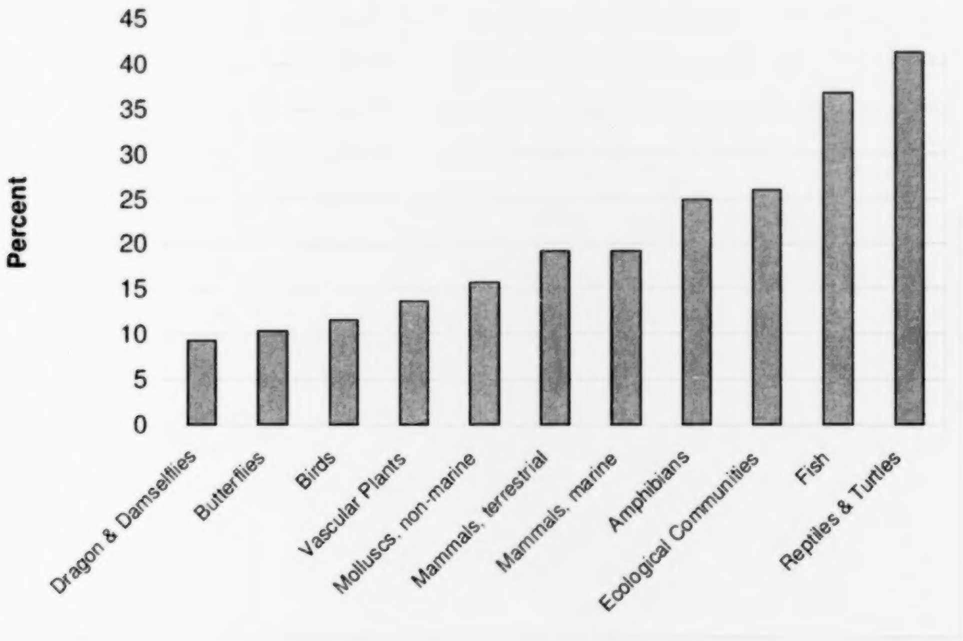
The BC Conservation Data Centre (CDC) determines and tracks rankings of species in the province with a colour-coded system. BC CDC uses a species tracking system developed by The Nature Conservancy (United States). This system is widely used in North America and enables comparisons among jurisdictions that use the same system (for an overview see *http://wlapwww.gov.bc.ca/wld/documents/ranking.pdf*).

This indicator presents the number of species and ecological communities included on the current provincial Red list. It does not include the five species extinct in B.C. Some subspecies or individual populations are listed separately by CDC. To be consistent with CDC listings, these listings were left as individual occurrences in the data set and were not combined as one occurrence under the species name. The total number of known species includes all species and populations on the Red, Blue, and Yellow lists. It does not include alien or extinct species.

Ecological communities are assemblages of plant species that can occur together and have the potential to interact with one another. They include natural plant communities and plant associations and the full range of ecosystems that occur in British Columbia (for more information, see *www.env.gov.bc.ca/cdc/ecology/index.html*). For details on how CDC determines whether an ecological community is endangered see: *www.env.gov.bc.ca/cdc/documents/ConsStatusAssessFactors.pdf*.

As of February 2007, the B.C. Red list contained 168 animals (15.5% of known animal species in B.C.), 322 vascular plants (13.7%), and 159 ecological communities (26.0%) (Figure 4, Table 1). The animals included vertebrates (amphibians, reptiles, and turtles, freshwater fish, marine and terrestrial mammals, and birds) and some invertebrates (butterflies, dragonflies, and nonmarine molluscs).

Figure 4. Red-listed species in B.C., by species group, as a percentage of the known number of native species in each group. Ecological communities are also included.



Source: BC Conservation Data Centre 2007.

Table 1. Red-listed species and ecological communities in B.C.

Group	Number Red listed	Total number known	% Red listed
Dragon- and damselflies	8	86	9.3
Butterflies	22	213	10.3
Birds	43	371	11.6
Molluscs, nonmarine	22	140	15.7
Mammals, terrestrial	23	120	19.2
Mammals, marine	5	26	19.2
Amphibians	5	20	25.0
Fish, freshwater	33	90	36.7
Reptiles and turtles	7	17	41.2
Total animals	168	1,083	15.5
Vascular plants	322	2,346	13.7
Ecological communities	159	611	26.0

Source: BC Conservation Data Centre 2007.

Note that some groups of species have not been fully assessed. For example, nonvascular plants, such as mosses, and invertebrates, including many of the insects, spiders, millipedes, and centipedes, have not been assessed across the range of known species. This indicator includes only a few groups of invertebrates and does not include nonvascular plants.

Interpretation

Although endangered and threatened species as a percentage of known species has been reported in previous Environmental Trends reports, it is not possible to compare previous and current data to establish a trend. As changes in the number of species included on the Red list (or Blue and Yellow lists) are often due to changes in taxonomy or assessment methods, these data simply provide a "snapshot" of the current status of endangered species and ecosystems in the province.

The proportion of a particular species group on B.C.'s Red list ranges from about 10% of known species in that group to just over 40%. The groups with the greatest number of Red-listed species are freshwater fish (37%) and reptiles and turtles (41%). For most animal groups included in this indicator, habitat modification and destruction is a major threat (Venter et al. 2006).

The Red-listed fish include six populations of white sturgeon, each of which is listed individually in CDC's database. In B.C., white sturgeon are found only in the Fraser and Columbia river systems. In the past they were threatened by overfishing and they continue to be threatened by habitat changes such as dams, altered river flow, channel dredging, and loss of wetland (COSEWIC 2003c). Four of the six white sturgeon populations listed by CDC can no longer be fished, and poaching remains a concern. The lower and middle Fraser populations still support catch-and-release fisheries. The Red-listed freshwater fish also include eight stickleback species, all of which have a distribution restricted to only one or a few lakes in B.C.

There are only 17 known reptile and turtle species in B.C.; of these, 7 are Red-listed: 3 turtles, 3 snakes, and 1 lizard (3 of these are extirpated).

The CDC recognizes 2,346 known vascular plant species in B.C.; 322 of these are on the Red list. Vascular plants include ferns and fern allies, coniferous trees, and flowering plants. Habitat loss and alien species are frequent reasons for vascular plant populations becoming endangered (e.g., BCMELP 1999a,b; CESCC 2006).

Ecological communities are associations of species that occur together and interact with each other in terrestrial, freshwater, and marine habitats. Many of the ecological communities recognized by CDC are terrestrial, and these are usually classified by the type of vegetation they contain (CDC 2004). Other communities may be classified using specific information about vegetation structure, site disturbance, or soil and terrain characteristics (CDC 2006). Of the 611 ecological communities that CDC includes in its database, over one-quarter (159) are Red-listed. Many ecological communities are on the Red list because they occupy only a small area in the province, and are therefore particularly vulnerable to threats such as climate change, habitat fragmentation and loss, poor grazing practices, invasion of alien plants, or recreational use (e.g., BCMSRM 2004a,b). Fire suppression over the last 150 years has also altered ecological communities by allowing other plant species to invade. For example, fire suppression in some areas where Garry oak once dominated has allowed Douglas-fir to take over (BCMELP 1993).

Many estuary and wetland ecosystems have been placed on the Red list because of activities such as dredging, draining and in-filling, water pollution, and invasion by alien plants (BCMOE 2006b).

Supplementary Information: How does the status of species at risk in B.C. compare with other provinces and territories?

The Canadian Endangered Species Conservation Council (CESCC) first assessed the status of a variety of species groups in 2000. These data were updated for 2005 and published in a report titled *Wild Species 2005: The General Status of Species in Canada*. The CESCC aims to determine what species are found in Canada, where they are found, and what their status is in Canada as a whole as well as in each province, territory, and ocean region. Four ocean regions—Pacific Ocean, Western Arctic Ocean, Eastern Arctic Ocean, and Atlantic Ocean—were included in their analysis because it is often difficult to associate whales and other marine species with a single province or territory.

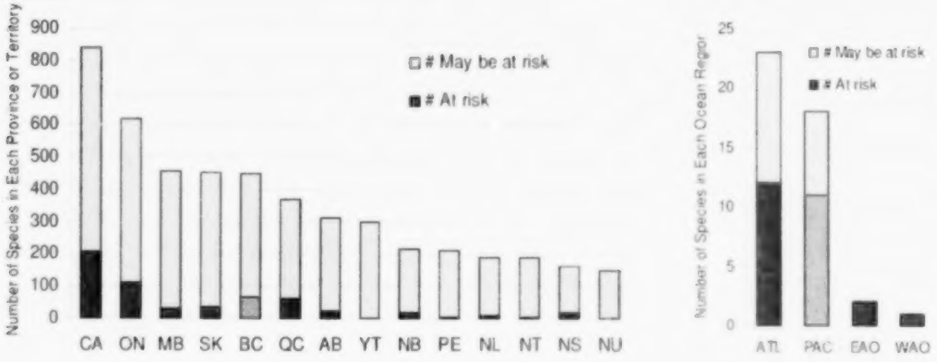
In total, 7,732 species are included in the 2005 data set. It includes all vertebrate species (amphibians, reptiles, freshwater and marine fishes, birds, mammals), all vascular plant species (ferns and fern allies, coniferous trees, flowering plants), and four groups of invertebrates (freshwater mussels, crayfish, dragon- and damselflies, tiger beetles). Based on the latest available information from provincial and territorial rankings, COSEWIC assessments, and species experts, each species was assigned to one of ten categories: Extinct, Extirpated, At Risk, May Be At Risk, Sensitive, Secure, Undetermined, Not Assessed, Exotic, or Accidental. Ranks were determined for each jurisdiction using a set of pre-defined criteria and then rolled up for the species in Canada as a whole. The group of species considered to be At Risk or May Be At Risk corresponds roughly to the BC CDC Red list of species, but without the subspecies or significant populations that are included on the B.C. lists. Also, the CESCC report distinguishes species At Risk from those that May Be At Risk based on whether a formal, detailed assessment of the species status has been completed.

Many species were not assessed in the Wild Species 2005 analysis. CESCC (2006) reports that Canada contains at least 70,000 recorded species and almost as many that have not been recorded (meaning that they are new to science or are known but not yet documented in Canada). Only 10% of recorded species were assessed and reported in Wild Species 2005, and possibly as few as 5% of all Canadian species. Species groups that were only partially assessed or not assessed at all include spiders, crustaceans, beetles, worms, mosses, fungi, algae, and the vast majority of invertebrates. For future reports, CESCC intends to expand the list of species groups assessed.

The number of species assessed was the total of species in all ten categories (therefore, it includes alien species). In the 2005 assessment, B.C. ranked fourth among the provinces and territories for the number of species considered At Risk or May Be At Risk (Figure 5). These data include 64 At Risk species and 382 May Be At Risk species, representing 1.8% and 10.5%, respectively, of all assessed species in B.C. (Table 2). For individual species groups, B.C.'s rank among provinces and territories changes: B.C. has the largest number of endangered amphibian, bird, fish, and mammal species. This result may be due in part to B.C.'s efforts to assess species status in the province, as well as to the large number of species that live in B.C. Nonetheless, the results indicate that B.C. has many species that are at risk of extirpation.

Of the four ocean regions, the Pacific Ocean ranks second with 11 species At Risk and 7 that May Be At Risk (Figure 5). Eight of the 18 marine mammals in these two categories are B.C. species, and all 8 are classified as being At Risk.

Figure 5. The number of species in Canada and in each province, territory, and ocean region that are classified as At Risk or May Be At Risk by the Canadian Endangered Species Conservation Council in 2005.



Source: Canadian Endangered Species Conservation Council (CESCC) 2006.

Note: Numbers for Canada are not a sum of the provinces and territories. Data for the ocean regions included only fishes, reptiles, and mammals. ATL = Atlantic, PAC = Pacific, EAO =Eastern Arctic Ocean, WEO = Western Arctic Ocean.

Table 2. Number of species (and proportion of total assessed) classified as At Risk or May Be At Risk by the Canadian Endangered Species Conservation Council in 2006.

	At Risk	May Be At Risk	Risk + May Be At Risk	Number of species assessed
Canada	206 (2.7%)	634 (8.2%)	840 (10.9%)	7,732
Ontario	109 (2.7%)	511 (12.6%)	620 (15.3%)	4,052
Manitoba	29 (1.2%)	426 (17.5%)	455 (18.7%)	2,440
Saskatchewan	34 (1.5%)	418 (18.1%)	452 (19.6%)	2,308
British Columbia	64 (1.8%)	382 (10.5%)	446 (12.3%)	3,628
Quebec	60 (1.8%)	308 (9.3%)	368 (11.1%)	3,328
Alberta	24 (1.0%)	286 (11.3%)	310 (12.2%)	2,535
Yukon	1 (0.1%)	296 (18.0%)	297 (18.0%)	1,649
New Brunswick	17 (0.7%)	200 (8.5%)	217 (9.2%)	2,362
Prince Edward Island	3 (0.2%)	208 (13.5%)	211 (13.7%)	1,537
Newfoundland	8 (0.4%)	181 (10.1%)	189 (10.5%)	1,799
Northwest Territories	4 (0.3%)	183 (11.9%)	187 (12.1%)	1,544
Nova Scotia	18 (0.8%)	143 (6.1%)	161 (6.8%)	2,362
Nunavut	2 (0.2%)	149 (14.6%)	151 (14.8%)	1,022
Atlantic Ocean	12 (1.4%)	11 (1.3%)	23 (2.6%)	871
Pacific Ocean	11 (2.4%)	7 (1.5%)	18 (3.9%)	457
Eastern Arctic Ocean	2 (1.2%)	0	2 (1.2%)	165
Western Arctic Ocean	1 (1.2%)	0	1 (1.2%)	81

Source: Canadian Endangered Species Conservation Council (CESCC 2006).

Note: Numbers for Canada are not a sum of the provinces and territories. Data for ocean regions include only fishes, reptiles, and mammals.

Supplementary information: Status and population trends for selected wildlife in B.C.

Mountain Caribou

The caribou of North America belong to a single species (*Rangifer tarandus*), with four living subspecies. Only one subspecies, the woodland caribou (*R. t. caribou*), currently lives within British Columbia. Woodland caribou are classified into three ecotypes: mountain (found primarily in the Cariboo, Selkirk, Purcell, and Monashee mountains of southeastern B.C.); northern (found from the Yukon border to the western Chilcotin and east to the foothills of the Rocky Mountains), and boreal (in the northeastern part of the province).

Only 1,900 mountain caribou remain in the province, down from the estimate of 2,300 animals in 2000. The population in B.C. represents almost the entire global population of this ecotype, which has been placed on the provincial Red list by the CDC and has been assessed as Threatened by COSEWIC.

Eighteen herds make up the mountain caribou ecotype. Each herd occupies one or a few distinct ranges in southeastern B.C. (Figure 6). Although the herds are all the same species, they tend to remain isolated from each other (B.C. Mountain Caribou Science Team 2005). Most have been studied with aerial surveys since the early 1990s, and some radio telemetry tracking has also been done.

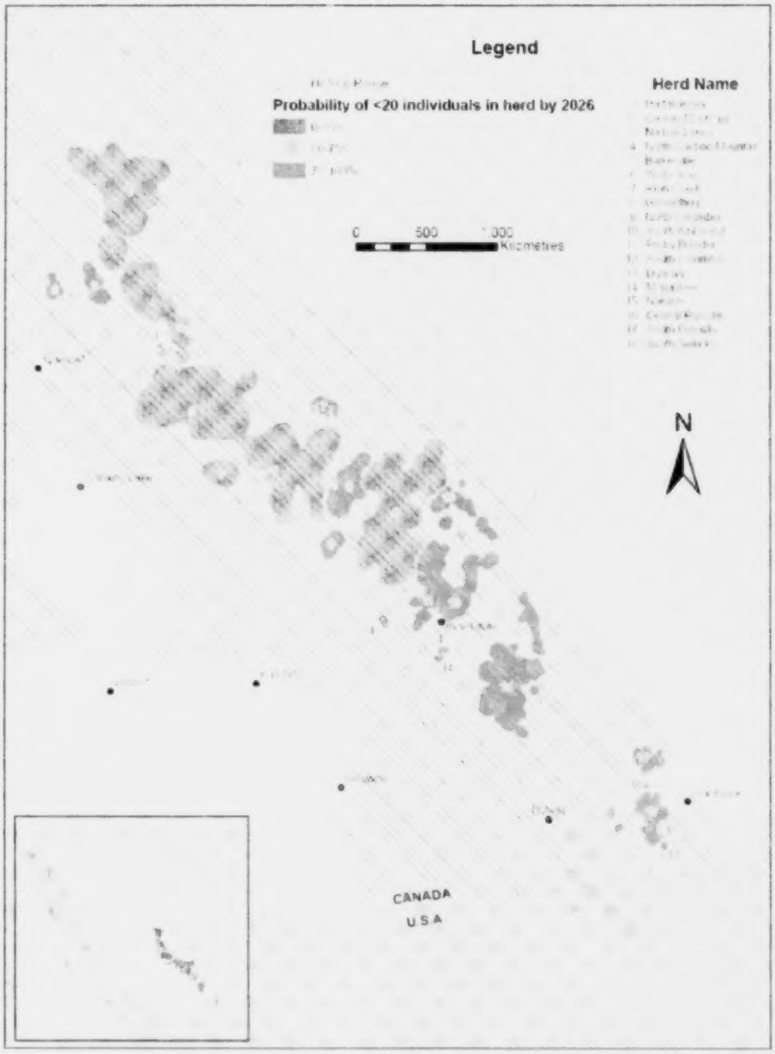
This analysis reports the extinction risk for 18 mountain caribou herds (Table 3). Population estimates from 10–15 years of surveys and tracking data were used to project the likelihood of each herd declining to fewer than 20 individuals within three generations (approximately 20 years, by 2026). When a herd dwindles to fewer than 20 individuals, it is unlikely to be able to rebound.

Two herds—George Mountain and Central Purcells—were already extinct in 2006. Six existing herds were found to be 100% likely to be extinct by 2026. Four herds had a more than 75% chance of becoming extinct by 2026 and two herds had a 50–75% chance of extinction by 2026. Only four herds had less than a 25% chance of becoming extinct. If these four herds are the only ones to persist and if they maintain their 2006 estimated population, the total population of the mountain caribou ecotype in 2026 would be about 1,500 animals. This is a loss of 20% of the current population.

Mountain caribou are threatened by several related factors: habitat change, disturbance, predation, and climate change (B.C. Mountain Caribou Science Team 2005). Habitat has been lost or fragmented by human activities such as logging, settlement, road building, and recreation, and by forest fires, natural and started by humans. This loss of habitat decreases the connectivity between large area of suitable habitat and makes populations more isolated (Thomas and Gray 2002). Loss of old-growth trees reduces the available habitat for lichens, which caribou eat in the winter (B.C. Mountain Caribou Science Team 2005). Disturbance by human activities, especially in the winter, can affect caribou behaviour and displace them from parts of their habitat. Predation continues to contribute to caribou loss. Climate change has several potential effects on caribou and their habitat, including changes in the amount and location of snowfall in winter, the frequency of wildfires, and the distribution of suitable habitat.

It is estimated that mountain caribou are now extirpated in 43% of their historic range (B.C. Mountain Caribou Technical Advisory Committee 2002). In October 2007, the province announced the Mountain Caribou Recovery Implementation Plan, which is a collaborative approach with conservation organizations, First Nations, the forest industry, and outdoor recreation groups aimed at restoring the mountain caribou population to pre-1995 levels throughout their existing range. The long-term survival, the persistence of mountain caribou will depend on a supply of large, contiguous areas of suitable summer and winter habitat with little or no human disturbance.

Figure 6. Current location and extinction risk of 18 mountain caribou herds in southeastern B.C.


Legend
Probability of <20 individuals in herd by 2026
Herd Name
0
500
1,000
Kilometres
N
CANADA
U.S.A.

Sources: Probability data from Ecosystems Branch, Ministry of Environment, 2006. Map distribution data from the provincial data warehouse (updated December 1, 2002).
Notes: The historic range shown on this map indicates the area of southeastern B.C. thought to have been occupied by woodland caribou. The historic range layer was created specifically for this map and does not correspond to extirpated range data that are housed in the provincial data warehouse.

Table 3. Population estimates for mountain caribou ecotype herds and risk of extinction (probability of <20 animals by 2026).

Map no.	Herd name	Population estimate, 2006	Risk of extinction (percent)
1	Hart Ranges	717	0
2	George Mountain	0	Extirpated
3	Narrow Lakes	40	92
4	North Cariboo Mountain	267	0
5	Barkerville	51	69
6	Wells Gray	422	0
7	Allan Creek	33	86
8	Groundhog	30	91
9	North Columbia	138	24
10	South Kinbasket	2	100
11	Frisby Boulder	19	100
12	South Columbia	29	100
13	Duncan	9	100
14	Monashee	8	100
15	Nakusp	85	83
16	Central Purcells	0	Extirpated
17	South Purcells	20	100
18	South Selkirks	37	54

Source: Ecosystems Branch, Ministry of Environment, 2006.

Note: Map numbers refers to Figure 6.

Killer Whales

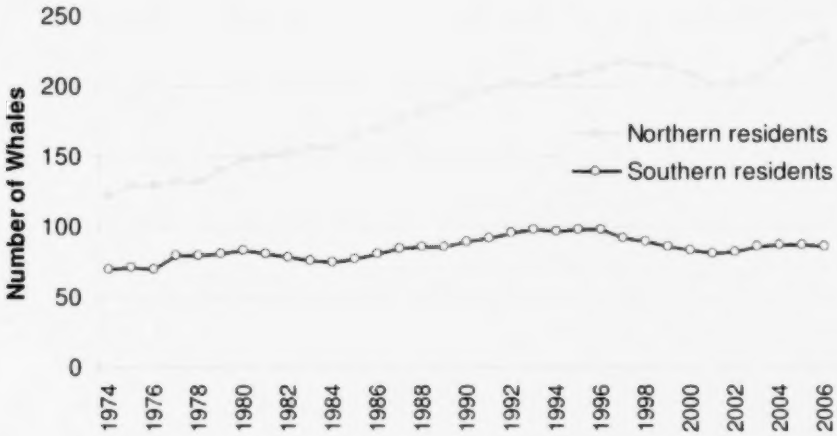
The status of killer whale populations is an indicator of the health of coastal ecosystems. They need clean water, healthy prey populations, and an environment that is large and quiet enough for them to maintain communication, locate and capture prey, and maintain other vital life functions (Killer Whale Recovery Team 2005).

Three distinct forms or ecotypes of killer whales live along the B.C. coast: transient, offshore, and resident. There are two different populations of the resident ecotype, designated southern residents and northern residents. The southern residents appear to be the most endangered, but all killer whale populations along the B.C. coast are considered to be at risk according to both federal and provincial criteria. A species recovery strategy has been drafted for the northern and southern resident populations.

Population counts of killer whales are made annually by the Center for Whale Research in Washington State for the southern residents and by the Cetacean Research Program, Fisheries and Oceans Canada, in Nanaimo for the northern residents. All whales in the southern population tend to be seen and counted during the year. In contrast, it is unusual to see all northern resident whales during the year because they travel widely along the B.C. coast. Counts are therefore generally less accurate for the northern residents.

Few data are available for killer whale populations before the early 1970s. It is known that 47 whales that were likely southern residents were captured and sent to aquariums in the late 1960s and early 1970s (Bigg et al. 1990). Live captures ended in 1973, and the population of southern residents increased to 83 whales by 1980 (Figure 7). After a surge in the number of breeding individuals, the population increased 34% over the next decade. The latest decline, which began in 1996, now appears to be reversing in some groups within the population, but not in others. In October 2006, three adult whales from the southern population died, causing concern for scientists (CWR 2007). Currently, the number of southern resident whales is still below the numbers estimated before the live captures occurred (Baird 1999).

Figure 7. Population trends for northern and southern resident killer whales of the B.C. coast, 1974–2006.



Sources: Center for Whale Research, Friday Harbor, Washington, USA, unpubl. data (southern population) Cetacean Research Program-DFO, Nanaimo, unpubl. Data (northern population).

At least 14 northern residents were captured between 1964 and 1973 (Bigg et al. 1990). Nonetheless, the northern population appears to have grown steadily from 1974 to 1991 (Figure 7). This may be because the northern population was larger to begin with, fewer individuals were captured, or they are generally exposed to less disturbance (Killer Whale Recovery Team 2005). After a slight decline in the late 1990s and early 2000s, the northern population now appears to be increasing again.

The small size of resident killer whale populations makes them particularly vulnerable to threats, such as reduced availability of prey, environmental contaminants (including oil spills), disturbances, and noise pollution. Even under ideal conditions, killer whale populations tend to recover slowly because they mature slowly and mature females calve only every 5–6 years (Killer Whale Recovery Team 2005).

Recent research strongly links the population changes in both southern and northern resident killer whales to the abundance of Chinook salmon, which suggests that prey limitation may be an important factor in recent declines (Ford et al. 2005). In fall 2006 and spring 2007, some pods of the southern resident population were seen off the California coast where they may have travelled in search of food (CWR 2007).

The health of resident killer whales, including reproductive and neurological development and immune system function, is a concern because research has found high levels of chemical contaminants in their tissues (Ross 2006). Members of the southern population, in particular, have high contaminant levels, likely because of foraging in their usual summer range along the highly populated and industrialized southern B.C. and northern Washington coasts. Contaminants in marine mammals are discussed in the "Contaminants" paper of this report.

Managed Salmon Stocks

The status of commercially fished salmon stocks in B.C. was reported in the B.C. Coastal Environment report (BCMOE 2006a); the following analysis provides an update. It shows the outlook for managed salmon stocks, by species, relative to an assessment of the target abundance of fish for each stock. The unit used in this indicator is a "stock" or "stock group," as defined for fisheries management purposes. The outlook for each stock depends on the effect of environmental factors, as well as on the effects of fishing and fisheries management.

The 2006 outlooks for managed B.C. salmon stocks were obtained from Fisheries and Oceans Canada's website (DFO 2006). The Stock Assessment group of DFO assigns each stock group to a status category that reflects the available information on recent returns for each stock and the expert opinion of fisheries managers. Where stock targets have not been formally described, the targets are either historical levels of abundance or are based on expert opinion (DFO 2003).

Stock status outlook is rated on a scale of 1 to 4, according to where the stock is forecast to be for the coming year:
1 = Stocks are less than 25% of target abundance or declining rapidly.
2 = Stocks are well below target or below target and declining.
3 = Stocks are within 25% of target and stable or increasing.
4 = Stocks are well above target abundance.

A total of 92 stock groups were considered in 2006 and outlooks were provided for 88 of them. More than a third (34) of the stocks were assigned a range of outlook categories, reflecting the geographic variation in status within the stock group and uncertainties in outlook. For this analysis, all stocks were grouped with the primary outlook category, thus stocks rated as 1, 1/2, 1/3, or 1/4 were counted together, stocks rated as 2, 2/3, or 2/4 were counted together, and stocks rated as 3 or 3/4 were counted together. The 2006 outlooks for 88 managed stock groups (populations) of sockeye, chinook, chum, coho, and pink salmon are shown in Table 4.

Table 4. Number of managed salmon stocks in B.C. by outlook category (1 to 4).

		Stock outlook category			
Species	No. stocks assessed	1, 1/2, 1/3, 1/4	2, 2/3, 2/4	3, 3/4	4
Sockeye	29	8	7	5	9
Chinook	24	4	8	9	3
Coho	18	3	6	7	2
Pink	6	0	4	2	0
Chum	11	3	2	5	1
Total	88	18	27	28	15
Proportion of total		20.5%	30.7%	31.8%	17.0%

Source: DFO 2006 Salmon Stock Outlook.

Note: No data were available for one stock of coho and three stocks of pink salmon.

For 2006, 43 of the stock groups assessed were forecast to be in Categories 3 and 4, meaning they are stable, or at or above target abundance; 27 stocks were in Category 2 or had part of the stock group rated in that category. These are considered sensitive stocks that are well below target abundance or well below target and declining. Eighteen stocks, including 4 chinook, 3 coho, 3 chum, and 8 sockeye stocks, were rated in Category 1. These are stocks of most conservation concern because they are below 25% of target abundance or are declining rapidly.

Results differ slightly from the 2004 outlooks reported previously (BCMOE 2006a, see *www.env.gov.bc.ca/soe/bcce/*). Outlooks for most stocks were the same, with a few stocks lower and some higher in 2006 than in 2004. The time period is much too short to show trends because there are year-to-year variations in stock status as different year classes of salmon return.

Fall-run Cultus Lake sockeye are of particular concern because 2006 should have been a peak year, but fewer spawners were expected to return than the critical level identified in the recovery plan. Threats to this population include fishing, habitat alteration in Cultus Lake, environmental fluctuations, and impacts related to parasites (early migration) and predators (freshwater predation). DFO-led recovery activities include rearing captive brood stock, removing pike minnows (predators), and controlling milfoil in the lake. Sackinaw Lake sockeye have virtually disappeared, with no spawners expected to return in 2007. Both Cultus and Sakinaw Sockeye have been assessed by COSEWIC as endangered.

Lower Mainland Steelhead

Steelhead (*Oncorhynchus mykiss*) are highly valued by recreational anglers and are important in First Nations ceremonial, social, and food fisheries. The Steelhead Recovery Plan (Lill 2002) classifies wild steelhead stocks relative to the capacity of a watershed to produce and sustain steelhead. The classification includes four categories: Routine Management Zone (steelhead not threatened, able to withstand modest catch and release fisheries); Special Concern (mostly small stocks that may need conservation, but little information available); Conservation Concern (steelhead estimated at 10–30% of habitat capacity); and Extreme Conservation Concern (steelhead at 10% or less of habitat capacity, risk of extinction).

The status of steelhead trout stocks over the whole province was reported in *Environmental Trends in British Columbia: 2002* (BCMWLAP 2002). About half of the stocks in B.C. assessed at that time were classified as healthy and about half were classified as Conservation Concern or Extreme Conservation Concern. Most of the latter were in the Lower Mainland and Vancouver Island.

In 2005, a study on the status of steelhead in the Fraser River watershed assessed stocks in 30 watersheds using methods similar to those used in 2002 (R. Ahrens, UBC Fisheries Centre, 2005, pers. comm.). Stocks in 10 of the 30 watersheds studied in 2002 were reassessed and 20 watersheds were assessed for the first time, for a total of 30 watersheds assessed in 2005 (Table 5). These assessments are part of the Steelhead Recovery Plan, which is completing stock assessments for all priority watersheds (*www.bccf.com/steelhead/about-steelhead.htm*). Methods and data were reported in detail in the B.C. Coastal Environment: 2006 report (BCMOE 2006a, see *www.env.gov.bc.ca/soe/bcce/*)

The 2005 study rated steelhead stocks in 3 watersheds as Conservation Concern and 27 as Extreme Conservation Concern. The status of stocks in 4 of the 10 watersheds assessed in 2002 had declined. Two moved from Conservation Concern to Extreme Conservation Concern and 2 watersheds that had been rated as healthy (Routine Management Zone) in 2002 declined to an Extreme Conservation Concern rating.

Table 5. Conservation status of steelhead for 30 Fraser River watersheds, 2005.

	Number of stocks assessed as	
Watershed	Extreme Conservation Concern	Conservation Concern
Lower Fraser	12	1
Mid Fraser summer	5	2
Fraser Canyon	4	–
Boundary Bay	3	–
Lower Fraser summer	3	–

Source: Data from R. Ahrens, Fisheries Centre UBC.

Declines in steelhead abundance are believed to have been caused by greatly reduced ocean survival combined with low productivity in freshwater habitats. Depending on the location of the stock, factors that may affect freshwater productivity include impacts from logging, urban development, agriculture, hydroelectric projects, and other changes to water flow (Lill 2002).

Steelhead populations elsewhere in the Pacific Northwest have also declined to the point of causing concern. For example, in May 2007, Puget Sound steelhead were listed as Threatened on the US endangered species list (NOAA 2007).

3. Secondary Indicator: Threats to species at risk in B.C.

This is a pressure indicator. It describes and ranks natural and human-caused threats to British Columbia species assessed as nationally at risk by COSEWIC.

A variety of threats, both naturally occurring and from human sources, can affect wildlife. Natural threats include interactions between native species, such a predation or competition for resources, and events such as storms and forest fires. Some species are threatened by innate characteristics such as being highly specialized or having a narrow ecological niche. Threats from human activity include habitat alteration and loss, pollution, over harvesting, and introduction of alien species. Climate change presents a long-term threat to species through physical impacts, such as more extreme weather or changes in river flow. Biological impacts of climate change include altered timing of development and reproduction or the expanded range of a competitor or predator.

Recovery strategies are being developed for species assessed by COSEWIC as extirpated, endangered, or threatened in Canada (see following indicator). To prepare these recovery strategies and determine the best use of conservation and recovery resources, we need to know which threats are most significant for these species.

Methodology and Data

The data used in this indicator were originally gathered for all species nationally at risk in Canada and published in Venter et al. (2006). For the B.C. analysis, the same database was used to extract the terrestrial, freshwater, and marine species that occur in B.C. Venter et al. (2006) compiled their database of species (which includes nationally extinct, extirpated, endangered, threatened, and special concern species) from COSEWIC information. Data sources were species status reports and executive summaries from COSEWIC and the Canadian Wildlife Service.

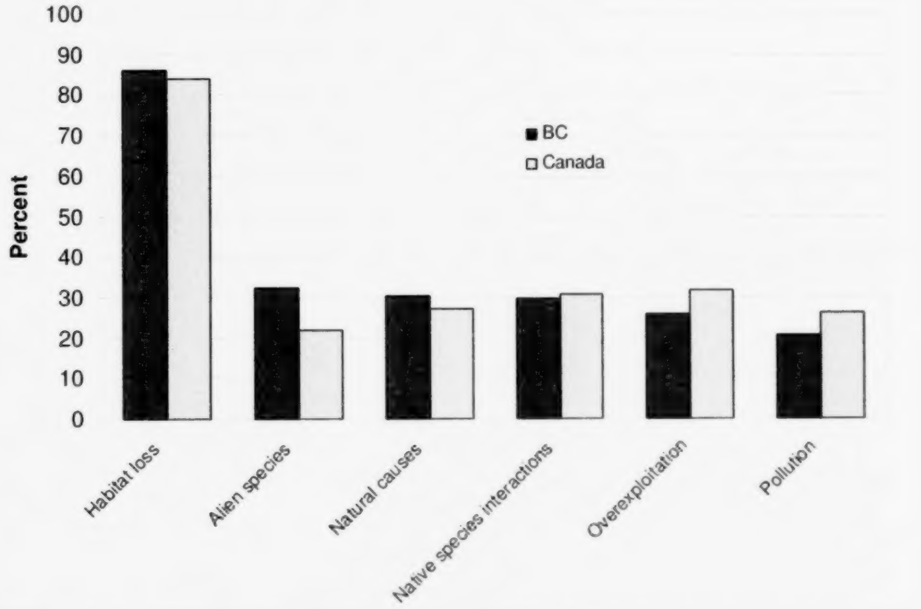
When Venter et al. (2006) compiled the data in June 2005, B.C. had 180 species in 12 species groups assessed to be nationally at risk by COSEWIC (36% of all such species at risk in Canada). Information was available on the threats facing 179 of the endangered species in B.C. One species, Haller's apple moss (*Bartramia halleriana*), had only potential or surmised threats listed and therefore was not included in the analysis.

Threats for the 179 species were grouped into six broad categories:

- Habitat loss: Reduction or degradation of required habitat through urbanization, agriculture, human disturbance, extraction, or infrastructure.
- Alien species: Competition, predation, hybridization, infection, or habitat modification by alien species. Cultivated species on farms and species native to Canada that had expanded or shifted their range naturally were not considered.
- Overexploitation: Intentional or unintentional harvest or persecution.
- Pollution: Chemical, thermal, or acoustic pollution, turbidity, and sedimentation.

- Native species interactions: An increase or decrease in a species' native competitors, predators, pathogens, prey, symbionts, or other organisms with which it interacts.
- Natural causes: Any random event (e.g., storm, drought, fire) or factor inherent to the species (e.g., limited dispersal, narrow niche).

Figure 8. Percentage of B.C.'s and Canada's species at risk* affected by six broad threat categories.



Source: Data for Canada from Venter et al. 2006. Original data for B.C. from COSEWIC database (2005) and analyzed according to methods outlined in Venter et al. 2006.

* Assessed as nationally at risk by COSEWIC.

Table 6. Number of Canada's and B.C.'s species at risk* that face six broad threat categories.

Species group	Habitat loss	Alien species	Natural causes	Native species interactions	Over-exploitation	Pollution
All Canadian species (n = 488)	409 84%	108 22%	133 27%	149 31%	154 32%	128 26%
All BC species (n = 179)	154 86%	58 32%	54 30%	53 30%	46 26%	37 21%
BC species only						
Vascular plants (n = 46)	40 87%	27 59%	15 33%	9 20%	2 4%	2 4%
Birds (n = 24)	22 92%	5 21%	3 13%	10 42%	7 29%	7 29%
Freshwater fish (n = 22)	18 82%	10 46%	4 18%	7 32%	4 18%	7 32%
Marine fish (n = 5)	4 80%	2 40%	3 60%	2 40%	5 100%	3 60%
Terrestrial mammals (n = 18)	16 89%	4 22%	3 17%	7 39%	7 39%	4 22%
Marine mammals (n = 13)	7 54%	0	1 8%	4 31%	10 77%	7 54%
Reptiles (n = 11)	11 100%	1 9%	7 64%	4 36%	7 64%	1 9%
Amphibians (n = 10)	9 90%	5 50%	7 70%	2 20%	1 10%	5 50%
Lepidoptera (n = 8)	8 100%	3 38%	0	1 13%	1 13%	0
Molluscs (n = 8)	7 88%	1 13%	4 50%	3 38%	2 25%	0
Mosses (n = 10)	9 90%	0	4 40%	1 10%	0	1 10%
Lichens (n = 4)	3 75%	0	3 75%	3 75%	0	0

Source: Data for Canada from Venter et al. 2006. Original data for B.C. from COSEWIC database (2005) and analyzed according to methods outlined in Venter et al. 2006.

Note: Categories do not sum to 100% for each species group because a species may appear in more than one threat category.

* Assessed as nationally at risk by COSEWIC.

Interpretation

Habitat loss was found to be the greatest threat to species at risk in B.C., affecting 86% of them (Figure 8, Table 6). Other threats listed were alien species (affecting 32% of species), native species interactions (30%), natural causes (30%), overexploitation (26%), and pollution (21%). Thirty percent were affected by only one threat, but most were affected by more than 2 of the 6 threats.

Comparison of the B.C. results to those for Canada showed similar threats. The main difference was that the second most important threat to B.C. species at risk was alien species, but nationally, this was the least common threat. The increased importance of alien species in B.C. may be due to the large proportion (31%) of B.C.'s at-risk species that are island species, found mainly on Vancouver Island, the Gulf Islands, and Haida Gwaii. Thirty-six of the 56 strictly island species in B.C., an astonishing 64%, were threatened by alien species compared to only 18% of B.C.'s mainland species (Venter et al. 2006).

Because many of the species groups contained only a small number of species, it is not possible to draw strong conclusions from the results. The analysis, however, did show that the relative importance of a threat type varied with the species (Table 6).

- Overexploitation was the most prevalent threat to marine mammals and marine fishes—more so than habitat loss. Reptiles were also vulnerable to overexploitation. However, it should be noted that if extirpated species had been included in the analysis, it would show that overexploitation or direct persecution has resulted in the loss of such species as Passenger Pigeon, wood and plains bison, and Sage Grouse from the province.
- Although habitat loss was important for all species, it threatened marine mammals less than other species.
- After habitat loss, alien species was the second greatest threat for butterflies and moths (Lepidoptera), freshwater fishes, and vascular plants. Half of amphibian species at risk were also threatened by alien species.
- Native species interactions were second to habitat loss for birds and terrestrial mammals, as were natural causes for reptiles, amphibians, molluscs, and mosses.
- Pollution threatened marine mammals, marine fishes, and amphibians, in particular.

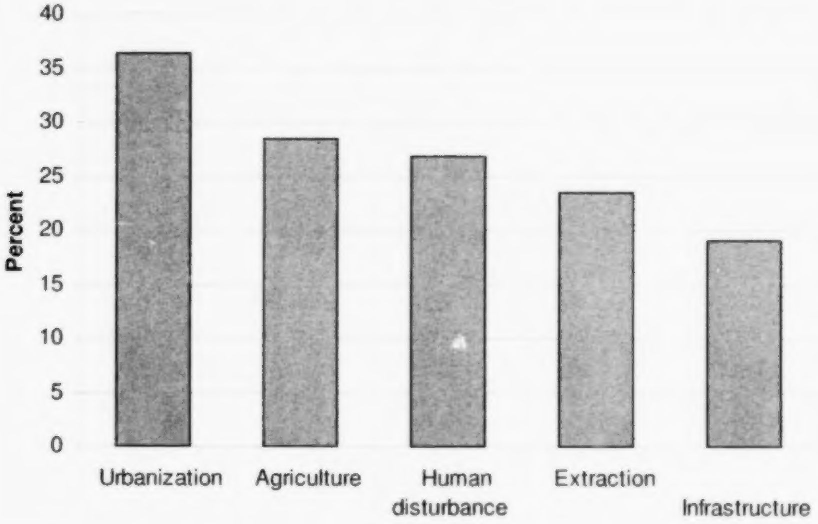
Supplementary Information: Details of threats from habitat loss

To provide more detail on habitat loss, this broader threat was subdivided into five subcategories for a finer scale analysis (Venter et al. 2006):

- Urbanization: Human settlements (urban, suburban, and rural), industrial and commercial buildings.
- Agriculture: Crops, wood plantations, nontimber plantations, livestock, ranching, aquaculture.

- Human disturbance: Recreation, tourism, military activities, research, transport, vehicle and vessel traffic.
- Extraction: Logging, mining, fishing, oil and gas extraction, groundwater and aquifer depletion.
- Infrastructure: Transportation, telecommunications, power lines, dams, impoundments, water diversions, pipeline construction.

Figure 9. Percentage of B.C.'s species at risk* affected by five types of habitat loss threat.



Source: Original data from COSEWIC database (2005) and analyzed according to methods outlined in Venter et al. 2006.

* Assessed as nationally at risk by COSEWIC.

The analysis showed that for all species combined, urbanization (36%) was the most common cause of habitat loss, followed by agriculture (29%), human disturbance (27%), extraction (24%), and infrastructure (19%) (Figure 9). The importance of specific types of habitat loss varied with species group (Table 7). For example, agriculture particularly threatened birds, terrestrial mammals, and reptiles, whereas human disturbance affected freshwater and marine fishes and marine mammals.

Table 7. The number of B.C.'s species at risk* affected by five types of habitat loss threats.

Species group	Urbanization	Agriculture	Human disturbance	Extraction	Infrastructure
All species (n = 179)	65 36%	51 29%	48 27%	42 24%	34 19%
Vascular plants (n = 46)	18 39%	4 9%	14 30%	6 13%	6 13%
Birds (n = 24)	9 38%	11 46%	3 13%	8 33%	1 4%
Freshwater fish (n = 22)	6 27%	3 14%	7 32%	2 9%	3 14%
Marine fish (n = 5)	1 20%	1 20%	3 60%	1 20%	3 60%
Terrestrial mammals (n = 18)	9 50%	13 72%	6 33%	8 44%	7 39%
Marine mammals (n = 13)	1 8%	0	6 46%	2 15%	0
Reptiles (n = 11)	8 73%	8 73%	0	3 27%	5 46%
Amphibians (n = 10)	4 40%	3 30%	1 10%	3 30%	5 50%
Butterflies and moths (n = 8)	3 38%	2 25%	2 25%	1 13%	0
Molluscs (n = 8)	3 38%	2 25%	2 25%	3 38%	1 13%
Mosses (n = 10)	3 30%	4 40%	3 30%	2 20%	3 30%
Lichens (n = 4)	0	0	1 25%	3 75%	0

Source: Original data from COSEWIC database (2005), analyzed according to methods outlined in Venter et al. 2006.

Note: One species may appear in more than one threat category, so the categories do not sum to 100% for each species group.

* Assessed as nationally at risk by COSEWIC.

4. Key Indicator: Progress toward completing recovery strategies for species at risk in B.C.

This is a response indicator. It addresses the question: What is being done to protect species at risk? The indicator shows the progress being made in one type of societal response to the issue—the development of species recovery strategies.

As signatory to the 1996 Accord for the Protection of Species at Risk, British Columbia is committed to action that will enable threatened and endangered species to recover. Recovery planning for species at risk involves the collaboration of government, industry, academia, and individuals. Planning involves preparing two documents: a recovery strategy and a recovery action plan (see text box "Recovery Planning"). Because is it unlikely that species would recover without human intervention, tracking the listed species that have recovery strategies and action plans is one measure of societal effort and commitment toward species recovery. A study by Taylor et al. (2005) found that in the United States, the status of species with a dedicated action plan for at least two years was more likely to improve than the status of species without a recovery plan.

This indicator measures progress in preparing recovery strategies for species that have been assessed by COSEWIC as extirpated, endangered, or threatened. The timeline for completion of recovery strategies is one year for endangered species and two years for threatened species. A management plan, which has less stringent content and format requirements, is required within three years of listing for species designated as special concern. This indicator reports only the status of recovery strategies; there was insufficient information to report on the current status of action plans. The indicator does provide an indirect measure of recovery action, however, because most recovery teams actively engage in implementation of recovery action even before the strategy is complete.

RECOVERY PLANNING

Recovery planning in Canada involves preparation of two types of documents:

- Recovery strategy: Details the information known about a species, its habitat, and threats to its survival. The document also outlines objectives and identifies additional information on species status and different recovery approaches that will help teams plan the recovery of the species.
- Recovery action plan: Includes specific projects or activities needed to meet the objectives outlined in the recovery strategy. The plan evaluates the socio-economic costs and benefits of improving the species' status.

An action plan together with a recovery strategy is often called a "recovery plan."

Methodology and Data

This indicator focuses on B.C. species at risk that have undergone formal status assessments by COSEWIC. Data on the progress of recovery strategies are compiled and tracked by the Ecosystems Branch, B.C. Ministry of Environment. The B.C. Ministry of Environment is the lead agency on recovery strategies for many B.C. terrestrial species and it is a co-leading agency for recovery teams working on freshwater fish and molluscs. The Canadian Wildlife Service is responsible for recovery strategies for migratory birds, and Fisheries and Oceans Canada is responsible for many marine mammals, fish, and invertebrate species; it also co-leads the recovery teams for freshwater fish and molluscs.

For COSEWIC data, the term "species" also includes subspecies and even specific populations of a single species where COSEWIC has deemed it necessary to assess these separately. There is not necessarily a one-to-one relationship between species and recovery strategies because recovery strategies may include multiple subspecies or populations, or even multiple species that inhabit the same ecological region. In some cases, several recovery strategies are being developed for a single species (e.g., caribou, white sturgeon).

Table 8. Progress, by species group, on development of recovery strategies for B.C. species assessed by COSEWIC as extirpated, endangered, and threatened (as of March 2007).

			In process			
Species group	No. listed species	Not yet started	Draft in preparation	Draft in review	Update in progress	Approved and published on SARA registry
Amphibians	6	0	2	3	1	0
Arthropods	8	0	3	3	0	2
Birds	16	1	5	9	0	1
Fish, freshwater	14	2	4	0	0	8
Fish, marine	5	0	2	3	0	0
Lichens	1	0	0	0	0	1
Mammals, marine	10	1	2	4	0	3
Mammals, terrestrial	10	1	6	2	1	0
Molluscs, aquatic	2	0	0	1	0	1
Molluscs, terrestrial	4	0	1	3	0	0
Mosses	8	1	2	5	0	0
Reptiles	9	1	3	2	2	1
Vascular plants	47	0	18	7	3	19
Total	140	7	48	42	7	36
	(100%)	(5%)	(34%)	(30%)	(5%)	(26%)

Sources: Species status: COSEWIC website: *www.cosewic.gc.ca/eng/sct5/index_e.cfm*. Data on progress in recovery: Ecosystems Branch, B.C. Ministry of Environment.

Note: Species assessed as Special Concern by COSEWIC are excluded because they do not require recovery strategies.

Interpretation

As of March 2007, recovery strategies for species at risk were in progress or completed across the full range of species groups and political jurisdictions (Table 8). Strategies were in process for 97 species (69%) and half of these were either completed and under review or were updates of existing strategies. An additional 36 species (26%) had an approved and published recovery strategy. These can be accessed through the SARA public registry (*www.sararegistry.gc.ca*). A strategy has not been started for 7 species.

Action plans that already exist for certain species, because they were part of previous processes, include:

- Marbled Murrelet (*Brachyramphus marmoratus*): a small seabird that uses old-growth coastal forests for nesting. An action plan was developed in 1993 (Kaiser et al. 1994) and recovery efforts continue.
- A subspecies of Peregrine Falcon (*Falco peregrinus anatum*): a predator threatened by habitat loss and small population size (Environment Canada 2004). An action plan was first developed in 1987 (Erickson et al. 1988). Initial goals have been met and an update is underway.
- Vancouver Island marmot (*Marmota vancouverensis*): a mammal living exclusively in alpine and subalpine habitats on a few Vancouver Island mountains. The first action plan was written in 1994; it was reassessed in 2000. Recovery efforts include research, monitoring, captive breeding, and reintroduction to the wild (Vancouver Island Marmot Recovery Team 2000).

As older plans such as these are revised they will better meet the requirements of SARA Action Plans. Recovery efforts for some species are initiated before recovery planning is completed, or even before the species is listed by COSEWIC.

Although writing and implementing a recovery plan does not guarantee improvement in the status of a species, it is a necessary step toward coordinating a recovery effort that has the greatest possible chance of being successful (Taylor et al. 2005). In addition to producing a plan, the process of recovery planning may encourage work on interim recovery measures. The process of regularly bringing together species experts, interest groups, industry representatives, and others to discuss the welfare of a species has other benefits, such as increasing communication and cooperation. Most recovery teams are also involved in implementing recovery actions, even before completing the recovery strategy or action plan.

As necessary as species recovery programs are, they are generally reactive, occurring once a species has declined to the point of near endangerment. Recovery is also generally slow and expensive—in the time it takes to improve the status of one species, several more may become at risk.

Supplementary Information: Conservation areas for rockfish recovery

Approximately 28 species of rockfish are caught commercially in B.C. They are mostly very long-lived fish with low productivity, which makes them vulnerable to overfishing. Inshore species are caught mainly in the groundfish hook and line fishery by commercial and recreational fishers. Offshore species are caught in the commercial longline, trap, and trawl fisheries.

The status of many offshore rockfish stocks is poorly understood; most stocks likely are fully exploited and some are overexploited. Bocaccio has been assessed by COSEWIC as Threatened, and COSEWIC is currently preparing species status reports for five species of rockfish.

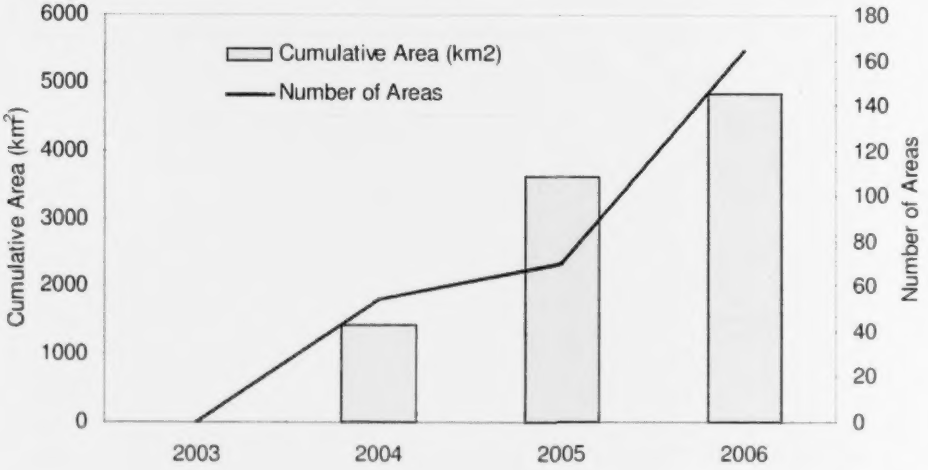
Serious conservation concerns for inshore rockfish species led to the development of the Rockfish/Lingcod Conservation Strategy in 2002 (DFO 2002). Under the strategy, 164 areas have been closed to fishing gear that causes rockfish mortality. These Rockfish Conservation Areas represent 30% of the rockfish habitat in the Strait of Georgia and just under 20% of rockfish habitat on the west coast of Vancouver Island, Central Coast, North Coast, and Haida Gwaii.

The management plan for the integrated commercial groundfish fishery outlines a sustainability strategy for inshore rockfish, including reducing bycatch, improving catch monitoring, and other steps to ensure a sustainable fishery (DFO 2007).

The area and number of rockfish conservation areas has increased annually (Figure 10). Although these areas are not in themselves permanent protected areas, they will likely be in place for at least one generation time of rockfish and probably much longer (30+ years). Yellow eye rockfish, for example, take 17 years to reach sexual maturity and can live to 115 years.

Some of these areas will probably be integrated into a system of Marine Protection Areas.

Figure 10. Rockfish conservation areas on the B.C. coast, 2003–2006.



Source: Groundfish Section, Pacific Biological Station, Fisheries and Oceans Canada.

5. Secondary Indicator: Number of alien species, by group, in B.C.

This is a pressure indicator. It addresses the questions: How many alien species have been introduced to B.C.? How much of a problem are invasive species in B.C.?

Alien, or exotic, organisms live outside their natural range usually because they have been deliberately or accidentally introduced there by humans. Because their natural predators or diseases are generally not present in the new environment, these alien species can become established and reproduce quickly. According to one estimate, about 10% of alien species become invasive (Menge and Branch 2001). Invasive alien species are particularly effective at becoming established in ecosystems under stress, such as those that are recently disturbed (Sorensen 1984).

Some studies suggest that alien species may be second only to habitat destruction in causing the loss of biological diversity worldwide (Vitousek et al. 1997). A recent study in Canada, however, ranked alien species last of six broad-scale threats to species at risk (Venter et al. 2006; also see Indicator 3: Threats to species at risk in B.C.). Current efforts to manage alien species have generally not been effective in controlling the problem (Simberloff et al. 2005). Global trade provides an increasing number of opportunities to transport organisms into non-native habitats where they may prey on, compete with, or alter the value of habitat for native organisms (Simberloff 2002).

In addition to the cost of ecological destruction, managing alien species is expensive. Economic costs include lost agricultural production and ecosystem services, control or eradication programs, and exclusion programs to keep out possible invaders. In 2000, alien species in the United States were estimated to cause environmental loss and damage worth US$137 billion per year (Pimental et al. 2000).

Methodology and Data

The data in this indicator came from three sources.

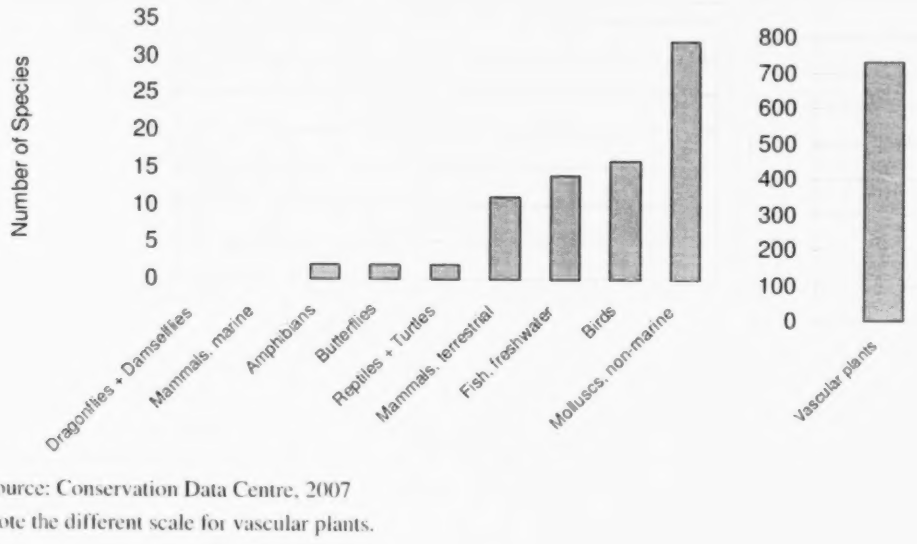
- The current number of alien species introduced to B.C. was compiled from the Conservation Data Centre (CDC) database (accessed 8 March 2007). The CDC database includes listings of both alien (exotic) and accidental species. Alien/exotic species have been moved beyond their natural range by human activity. Accidental species have moved beyond their natural range of their own accord, which occurs very rarely (L. Ramsay, B.C. Ministry of Environment, 2007, pers. comm.). Most accidental species are birds. Accidental species are not considered to be part of B.C.'s native fauna or flora, although if they eventually establish breeding populations, they would then be considered new immigrant species. For this indicator, only the species listed by CDC as "exotic" have been included.
- Trends in alien vascular plant species between 1996 and 2006 were compiled from an internal database maintained by the Research Branch of the B.C. Ministry of Forests and Range (British Columbia Plant Species Codes and Selected Attributes: Version 5, available at *www.for.gov.bc.ca/hre/becweb/resources/codes-standards/standards-species.html*). The data include several entries for each year, therefore the most recent entry was used for each year. An additional year of data, for 1994, was obtained from Douglas et al. 1994. To be considered an alien plant, a species must persist from year to year in natural or seminatural habitats (i.e., not in gardens).

- Trends in alien fish species between 1950 and 2005 were compiled by Hatfield and Pollard (2007) from a provincial database that documents individual occurrences of all fish species in B.C. The data came from biological surveys of freshwater systems in B.C. and were collected by multiple agencies and individuals. Although some geographic and species records were incomplete, there were enough complete data entries to analyze trends in alien fish species. The data set included species that have been introduced from outside B.C., along with three species (walleye, northern pike, and yellow perch) that have very limited native range in B.C. (all in the northeast of B.C.). These three species were included as aliens because they have been introduced to parts of B.C. that are a long way from their native B.C. ranges, often as migrants from introductions to lakes or rivers south of the Canada–US border (Hatfield and Pollard 2007).

Number of Alien Species in B.C.

As of March 2007, 809 alien species were recorded in B.C., representing nearly one-fifth of all recorded species, native and alien combined, in the province (Figure 11, Table 9). More than 90% of these alien species were vascular plants. Among animals the greatest number of alien species was in the nonmarine mollusc group (32 species or 17% of recorded nonmarine molluscs). The next largest group of aliens was birds (16 species or 4% of all birds), followed by freshwater fish (14 species or 14% of all fish), and terrestrial mammals (11 species or 8% of all mammals). There were no recorded alien species in the marine mammal and dragon- and damselflies groups. Although only 34 alien invertebrates were included in these data, it is known that there are more alien invertebrates in B.C., particularly in marine and estuarine ecosystems (see BCMOE 2006a). They were not included in this indicator, because data on these invertebrate groups have not yet been analyzed by the CDC.

Figure 11. The number of alien species in B.C., by species group, as of March 2007.



Source: Conservation Data Centre, 2007

Note the different scale for vascular plants.

Table 9. The number of alien species in B.C., by species group, as of March 2007.

Species group	Number of alien species	Percentage of all species in the group
Dragonflies + Damselflies	0	0
Mammals, marine	0	0
Amphibians	2	9.1%
Butterflies	2	0.9%
Reptiles + turtles	2	10.5%
Mammals, terrestrial	11	8.4%
Fish, freshwater	14	13.5%
Birds	16	4.1%
Molluscs, nonmarine	32	18.6%
Vascular plants	730	23.7%
Total	809	19.1%

Source: Conservation Data Centre, 2007.

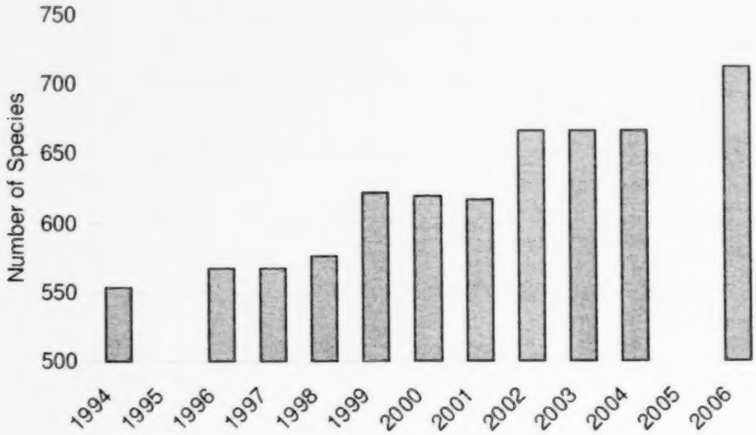
Note: Recorded species include Red-, Blue-, and Yellow-listed species and alien species.

Trends in Alien Vascular Plants

The number of alien vascular plant species in B.C. has increased steadily between 1994 and 2006 (Figure 12, Table 10). In 1994, 553 species were recorded and by 2006 there had been a 29% increase to 713 species. From 1999 to 2001, there was a small decline because five species were removed from the alien species list, possibly because they did not persist, their taxonomic identification was revised, or they had been misidentified (J. Penny, B.C. Ministry of Environment. 2007, pers. comm.).

Note that the trend data set lists 713 alien vascular plants for 2006 and the CDC data set of current status in early 2007 lists 730 species. The 17 species discrepancy is due to the difference in dates the data were obtained: the trend data were compiled October 2006 and the CDC data in March 2007. The CDC database is continually updated with new information, so by March 2007 it included 17 additional species not included in the October 2006 trend data.

Figure 12. Number of alien vascular plant species established in B.C., 1994 to 2006.



Sources: Douglas et al. 1994; BC Flora Database, Ministry of Forests and Range.

Table 10. Number and increase in alien vascular plant species established in B.C., 1994 to 2006.

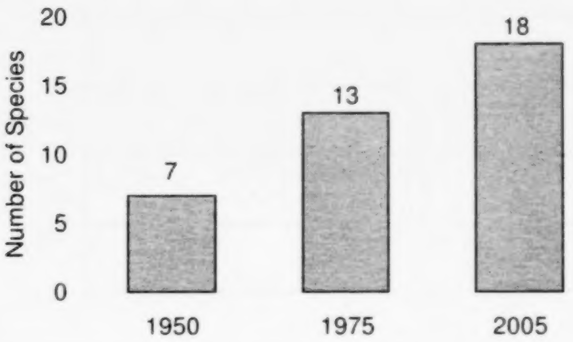
Year	Number of alien species	Change from 1994
1994	553	–
1996	567	+2.5%
1997	567	+2.5%
1998	576	+4.2%
1999	622	+12.5%
2000	620	+12.1%
2001	617	+11.6%
2002	667	+20.6%
2003	667	+20.6%
2004	667	+20.6%
2006	713	+28.9%

Sources: Douglas et al. 1994; BC Flora Database, Ministry of Forests and Range.

Trends in Alien Fish Species

The number of alien freshwater fish species has increased from 7 in 1950 to 18 in 2005 (Figure 13). In addition, the number of waterbodies that contain alien fish species has increased from 28 in 1950 to 625 in 2005 (Table 11).

Figure 13. Number of alien freshwater fish species in B.C. over a 55-year span.



Source: Hatfield and Pollard 2007.

Table 11. Number of waterbodies, by region, with one or more alien freshwater fish species.

Region	Waterbodies with alien species			No. of waterbodies surveyed
	1950	1975	2005	
1: Vancouver Island	4	37	84	104
2: Lower Mainland	4	28	57	93
3: Thompson	2	13	40	61
4: Kootenays	10	63	325	398
5: Cariboo	1	12	17	20
6: Skeena	1	3	6	11
7: Omineca	1	4	19	19
8: Okanagan	4	34	73	139
9: Peace	1	1	4	15
Total	28	195	625	860

Source: Hatfield and Pollard 2007.

Note: Some records in the database were not dated, so the total number of records differs from the final count in 2005.

Interpretation

Plants

Plants are overwhelmingly the most common group of alien species documented in B.C. About 65% of alien plants occur frequently and appear to be widely established (BCMOE 2006a). The number of alien plants is high, likely because they have been unintentionally imported along with livestock feed, as well as introduced for nursery and other agricultural purposes (Harding 1994). Others may have arrived on imported equipment or domesticated animals. Many of the most invasive plants (e.g., Scotch broom, purple loosestrife, baby's breath, Japanese knotweed) were intentionally planted as ornamentals and have escaped from gardens.

Although many alien plants arrived in B.C. at the time of and soon after European settlement, other alien plants continue to be introduced to the province today. In the 12 years from 1994 to 2006, more than 150 alien plants were introduced to natural habitats and became established.

Fish

Some of the increase since 1950 in the number of alien fish species and of waterbodies with alien fish in B.C. may be due to the fact that more watersheds have been surveyed over time. However, Hatfield and Pollard (2007) state that the pattern of increase likely represents a true trend in the spread of alien fish species within B.C. Provincial regions with the greatest increase in distribution of alien species have been those with the largest human population: Vancouver Island, Lower Mainland, Okanagan, and Kootenays. The general trend of increased distribution of alien species is probably more pronounced than shown by the data, because, with the exception of walleye, northern pike, and yellow perch, this data set does not include species native to B.C. that have been introduced into waters outside their natural range.

The data in Hatfield and Pollard (2007) indicate two patterns. First, observations of alien fish species distribution tend to be focussed around urban areas, both for species mainly introduced through authorized stockings (e.g., brook trout and brown trout) and for those predominantly introduced illegally (e.g., bass species, yellow perch, and catfish). Frequently, small lakes and streams near urban areas have been stocked to enhance fishing opportunities. A larger human population also increases the likelihood that unwanted pets will be released, that organisms from man-made ponds will escape, and that individuals who would like to create a fishery close to home will intentionally move fish. On the other hand, more aliens species may be recorded close to urban areas because there is easier access for monitoring and a greater need to study these watersheds.

The second pattern is that introductions are more concentrated in southern regions of the province, which may reflect some or all of the following:

- Environmental conditions. The milder climate in southern areas may be more hospitable to warm-water species such as bass, carp, and bullhead.
- Areas of high population density. A large proportion of B.C.'s population lives close to the US border, allowing for the factors discussed above for urban areas.
- Associated disturbance. The Columbia and Kootenay watersheds have experienced large-scale habitat changes from hydroelectric and flood-control dams. Converting natural riverine habitats to the still or slow-moving habitat found in reservoirs has been associated with replacement of native species by aliens that are better adapted to the new environment (Quist et al. 2003).
- Forestry-related activities. Increased stream water temperature, which frequently accompanies forestry activities, can displace coldwater species, such as cutthroat and bull trout, in favour of species with greater temperature tolerance, such as brown and brook trout

(Rieman et al. 2006). Although forestry occurs throughout most of B.C., the effect on alien species' distributions may be more relevant in southern watersheds where more alien species are already present.

- Proximity to the US border. Illegal introductions from populations in the US and natural northward dispersal in shared watersheds, such as the Columbia, Kootenay, and Flathead rivers, are both possibilities for B.C. waterbodies close to the US border. In the past, waterbodies in northwestern US states have been stocked with walleye, bass, and yellow perch. For example, the walleye in the B.C. portion of the Columbia system likely originated in Washington (Fuller et al. 1999).

Alien Species in General

The number of alien species reported here is a total from only some of the better known groups of organisms and is not the total number of alien species established in B.C. Alien microorganisms, insects, and other invertebrates are not well documented but are likely abundant. For example, ballast water in cargo ships may contain thousands of tiny organisms, including algae and zooplankton, in each cubic metre of water (Levings et al. 1998). More than 3,000 species of animals and plants are estimated to be transported around the world daily in ballast water (NRC 1996). With respect to insects, Smith (1994) identified more than 300 alien insect species in British Columbia. Some are serious economic pests and others were introduced intentionally as part of biological control programs for pests. Earthworms are another group of organisms that have been poorly documented in B.C. but that contain several alien species. The activity of many alien earthworms alter processes in the forest floor and ultimately affect biodiversity in native forests (Hendrix and Bohlen 2002). More comprehensive monitoring would likely find more species.

Although they carry potential (or realized) costs to ecosystems and to native commercial species, lucrative industries have sprung up around some alien species, especially in coastal waters. For example, several alien marine invertebrates are commercially valuable. The Manila clam (*Tapes philippinarum*), unintentionally introduced in the 1930s, has colonized much of the province's south coast where it apparently co-exists with native clams (DFO 2001; BCSGA 2004) and supports a commercial clam industry valued at $7.6 million in 2003 (DFO 2004). The introduction of Atlantic salmon aquaculture to the B.C. coast has simultaneously fuelled an industry worth more than $300 million annually (Statistics Canada 2005) and controversy over threats to wild salmon fisheries (e.g., Special Committee on Sustainable Aquaculture 2007).

Left uncontrolled, some alien species could have large negative impacts on provincial ecosystems and some commercial industries. Two alien species in particular that have not become established in B.C., but which are the target of ongoing quarantine and eradication efforts, are the Asian gypsy moth (*Lymantria dispar*) and sudden oak death (*Phytophthora ramorum*) (Hunt et al. 2006). The gypsy moth threatens forestry, agriculture, and nursery sectors as well as the native Garry oak forests (Agriculture Canada 1986; Humble and Stewart 1994). Sudden oak death, a fungus, also threatens the forestry, agriculture, and nursery sectors and numerous native plant species, including Garry oak, arbutus, big-leaf maple, salmonberry, and Douglas-fir (BCMAFF 2004).

The threat from invasive species continues to rise as a result of many global factors, including a thriving horticulture industry, an increase in human travel and export around the world, and climate change. Climate change may increase the number of alien species in B.C. as conditions become more favourable for their establishment and spread (Hunt et al. 2006). Warmer average temperatures would be more likely to improve survival through the winter and stimulate faster development of individuals during the summer.

Supplementary Information: Biological control of alien species in B.C.

Some alien vascular plants are particularly aggressive at outcompeting native species and altering native ecosystem dynamics. These aggressive alien plants are often termed invasive species. In an attempt to stop the spread of invasive plants and control the damage they cause, the BC Ministry of Forests and Range has a biocontrol program to release biological agents that feed on the invasives. Most biocontrol agents are insects, but a few are fungi, mainly rusts. Developing a biocontrol agent requires a large commitment of time (8–10 years) and funds to complete all the testing that must be done to ensure that the agent will be effective and will not harm native species.

Since the 1950s, 70 species of biocontrol agents have been released in B.C. to target 27 invasive plant species. Some of these 70 agents, generally those imported early in the program, have disappeared or have not survived in B.C. Two areas of particular focus for current biocontrol research are compatibility with habitats in the importing country and the effectiveness of the agent at controlling the plant species. Several agents may be released to control a single plant species. The aim is to weaken the invasive plant at as many points as possible—e.g., at the stem, root, and bud. This gives native species a chance to coexist with the invasive plant, or ideally, to outcompete it.

Biocontrol of invasive plants in Canada began in B.C. in 1952 with releases of several species of *Chrysolina* beetles to control St. John's wort (*Hypericum perforatum*) (Powell et al. 1994). The plant contains a toxin that causes grazing animals to become sensitive to sunlight and develop skin irritation. The biocontrol insects feed heavily on the plant's foliage and flower buds (BCMOFR 2007). They have been effective at controlling St. John's wort, reducing dense stands to only scattered plants (Powell et al. 1994).

Other invasive plants targeted by biocontrol programs include the following:

- Spotted knapweed (*Centaurea biebersteinii*) and diffuse knapweed (*Centaurea diffusa*), both of which rapidly colonize disturbed areas as well as outcompete native plants in undisturbed areas (Powell et al. 1994). Several species of moths, flies, and beetles have been released since 1975 for diffuse knapweed and since 1985 for spotted knapweed (BCMOFR 2007).
- Tansy ragwort (*Senecio jacobeae*), another invasive plant poisonous to livestock, has been the target of biocontrol releases since the 1960s (BCMOFR 2007).
- Leafy spurge (*Euphorbia esula*), a plant that can tolerate many ecological conditions, has been targeted since the mid-1980s with several biocontrol agents, mostly species of *Aphthona* beetles (BCMOFR 2007).

WHAT IS HAPPENING IN THE ENVIRONMENT?

With the current state of knowledge, indications are that the overall status of many species is declining in the province, thus biodiversity in B.C. in general appears to be declining. The status of only a small number of species is regularly monitored, however, and the state of knowledge of ecosystems, which are an integral part of biodiversity is even less complete than the understanding of single species.

Most often, species are listed as being at risk because of the impact of human activities. Urban, agricultural, and other developments can encroach on habitat; chemicals and other types of pollutants can alter habitat conditions; overexploitation of a species can reduce the number of individuals; and alien species can prey upon or compete with a native species. There are also naturally occurring factors that can contribute to a species' decline, such as predation, disease, and extreme events, such as fire and drought. The combination of these numerous pressures can disturb natural ecosystems, extirpate local populations, and impair natural processes (e.g., Solan et al. 2004).

Results of analyses for the indicators in this paper indicate the following:

- The overall status of mammals and freshwater fish has declined over the past 13–15 years, as shown by the increase in species with a deteriorating conservation status. Red-listed vascular plants also showed an overall deterioration in conservation status during a 9-year period. The situation for birds is difficult to interpret because the number of new immigrant species has increased. More than one-third of fish, reptile, and turtle species in B.C. are on the provincial Red list of species at risk.
- B.C.'s ecosystems are incredibly diverse and have resulted in an enormous variety of plant and animal species throughout the province. Compared with other provinces and territories in Canada, B.C. has the largest number of amphibians, birds, fish, and mammals that are considered to be at risk according to COSEWIC and CDC designations.
- Federal accords and legislation have prompted the development of recovery strategies for most species that have been assessed by COSEWIC as being At Risk and occur in the province. Recovery strategies were in progress or completed for 69% of species, across the full range of species groups. An additional 26% of species had an approved and published recovery strategy. As necessary as species recovery programs are, they are generally reactive, slow, and expensive.
- Most of the B.C. species assessed to be nationally at risk face two or more threats, whether from natural or human sources. Habitat loss threatens 86% of these species, more than twice as many species as are threatened by any other examined threat. The large number of B.C. species threatened by habitat loss is consistent with results for Canada as a whole, as well as with results from elsewhere in the world (e.g., Baillie et al. 2004). Within the habitat loss category, most species were threatened by urbanization and agriculture. With continued population growth and development activities, habitat loss and alteration will continue to be a critical issue for many species.
- Alien species were the second greatest threat to B.C.'s species, based on analysis of the province's species that are nationally at risk. Although this differs from Canada-wide results,

the results are consistent with studies elsewhere (Miller et al. 1989; Wilcove et al. 1998) and likely reflect the large number of island species in B.C. More than 700 species of alien vascular plants have become established in B.C., and some of these have become serious problems. The provincial tracking system records 45 species of alien vertebrates and 34 species of invertebrates as introduced in B.C., but the true number of alien invertebrates is undoubtedly higher.

Species currently at risk are threatened by the growing human population and activities that place stress on the natural environment. In the long term, however, global climate change is likely to become the greatest threat to biodiversity in many regions of the world, resulting in severe impacts and extinctions as it compounds the effects of local threats (Thomas et al. 2004). Climate change has the potential to increase the frequency and extent of disturbances, such as fire and insect outbreaks (McKenzie et al. 2004), to create favourable conditions for invasive species, and to produce ecological shifts that may occur faster than species can adapt (Opdam and Wascher 2004). Although it is not possible to predict how much climate change will affect biodiversity in B.C., it is likely that it will create additional pressure in ecosystems that are already stressed in many ways.

Estimates of the global rate at which organisms are becoming extinct range from 100 to 1,000 times the historically "normal" rate of extinction, and scenarios for the future suggest this may increase a further 10 times (UNEP 2001; MEA 2005b). In terms of the global state of organisms, 33% of amphibian species (Stuart et al. 2004), 12% of birds (Birdlife International 2004), and 23% of mammals (IUCN 2003a) are considered vulnerable, endangered, or critically endangered.

This is a critical issue because research shows that the composition and richness of ecosystems can be changed dramatically by the loss of just one species. Loss of certain key species leads to rapid, systematic loss of others (Raffaelli 2004) and can result in reduced ecosystem function and stability because surviving species may not adequately replace the function of those lost (Solan et al. 2004). A damaged ecosystem becomes increasingly vulnerable to threats that it may formerly have been able to resist, such as invasive plants (Zavaleta and Hulvey 2004). Damaged ecosystems can no longer support the host of "ecosystem services" (e.g., MEA 2005a) on which humans are entirely dependent:

- Providing food, water, timber, and fibre harvests.
- Regulating climate, floods, water quality, and waste treatment.
- Supporting ecosystem functions, such as soil formation, pollination, and nutrient cycling.
- Supporting cultural activities, such as recreation, aesthetic enjoyment, and spiritual fulfilment.

Although ecosystem services provide life support for the planet, they are undervalued and poorly understood (Emerton and Bos 2004). In one analysis of the value of ecosystem services in B.C.'s lower Fraser valley, the authors concluded that protecting this ecosystem may save society hundreds of millions of dollars every year (Olewiler 2004).

Globally, the human use of all ecosystem services is growing rapidly, and yet recent research shows that approximately 60% of Earth's ecosystem services are being degraded or used unsustainably (MEA 2005a). The continued provision of ecosystem services relies on healthy ecosystems, of which the diversity of species is a major and vulnerable part. Recent research has found that vital ecosystem functions, such as capturing carbon dioxide and purifying water, depend on many more species than previously thought—meaning that the impact of losing biodiversity may have been underestimated (Hector and Bagchi 2007).

WHAT IS BEING DONE ABOUT SPECIES CONSERVATION?

The status of species is affected by many areas of human activity, including industrial processes, land conversion, forestry, fishing and other harvesting, agriculture, environmental contamination, and climate change. The following key programs and policies address such pressures on individual species and ecosystems.

Key Federal Government Initiatives

- UN Convention on Biological Diversity (CBD): In 1992, Canada, with support from provincial and territorial governments, was the first industrialized nation to sign this convention. The main objective of the CBD is to achieve, by 2010, a significant reduction in the current rate of loss of biodiversity at global, national, and regional levels. The Canadian Biodiversity Strategy, published in 1996, is intended to guide implementation of the CBD in Canada. (*www.biodiv.org/default.shtml*)
- Species at risk agreements and legislation: In 1996, the Accord for the Protection of Species at Risk committed provinces and territories to work with the federal government to protect and recover species at risk. The federal *Species at Risk Act* (SARA), came into force in June 2004. It is intended to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct; to provide for the recovery of endangered or threatened species; and to encourage the management of other species to prevent them from becoming at risk. SARA has prompted recovery planning for species at risk all across the country. British Columbia and the federal government have endorsed a bilateral agreement to work cooperatively on the implementation of SARA. (*www.sararegistry.gc.ca/*).
- Committee on the Status of Endangered Wildlife in Canada: COSEWIC is an independent body of experts who use scientific, aboriginal, and community knowledge to classify species in Canada as extirpated, endangered, threatened, of special concern, or not at risk. COSEWIC includes representation from British Columbia. Under the *Species at Risk Act*, the government of Canada will take COSEWIC's recommendations into consideration when establishing the legal list of species at risk. (*www.cosewic.gc.ca/index.htm*)
- Invasive Alien Species Strategy for Canada: Published in 2004, the intent is to address the threat of invasive species to Canada's wildlife, forests, fisheries, and other resource sectors. The strategy prioritizes key actions and identifies the need for action plans on aquatic invaders, invasive plants, and introduced terrestrial animals. (*www.cbin.ec.gc.ca/primers/ias_invasives.cfm*)
- Canada's Oceans Strategy: Announced in 2002, the main objectives are understanding and protecting the marine environment, supporting sustainable economic development, and

providing international leadership and oceans governance. The strategy involves collaboration between the federal government, provinces, First Nations, oceans industries, academia, and the general public, as well as with other nations. In 2004, the federal and provincial governments signed a Memorandum of Understanding Respecting the Implementation of Canada's Oceans Strategy on the Pacific Coast of Canada to formalize the commitment of both governments to achieve the objectives. (*www.cos-soc.gc.ca/dir/cos-soc_e.asp*)

Key Provincial Government Initiatives

- B.C. Conservation Data Centre: The CDC systematically collects and disseminates information on plants, animals, and ecosystems (ecological communities) at risk in British Columbia. This information is compiled and maintained in a computerized database that provides a centralized and scientific source of information on the status, locations, and level of protection of these organisms and ecosystems. (*www.env.gov.bc.ca/cdc/*)
- Strategic land use planning: Strategic land use plans, which include identifying key areas for management and conservation of biodiversity, are under way and at various stages of completion throughout the province. (*ilmbwww.gov.bc.ca/lup/*)
- Revisions to the *Wildlife Act*: The *Wildlife Act* regulates wildlife harvest, establishes wildlife management areas and critical wildlife areas, and designates endangered species. In 2004, this act was amended to allow the provincial Cabinet to designate the full range of species provided for in the federal *Species at Risk Act*, including plants and invertebrates at risk. It expands the range of species that can be added to the extirpated, endangered, and threatened lists and allows for the protection of the habitat of species at risk. At time of writing (July 2007), the *Wildlife Act* was under review to make it more relevant to other issues, such as alien and invasive species, wildlife diseases, and ecotourism (BCMOE 2007).
- Species at risk under the *Forest and Range Practices Act*: In 2004, the Minister of Environment identified 39 species, all previously listed by COSEWIC, as Identified Wildlife, meaning that these species now require a greater level of consideration when planning forestry and range activities.
- In October 2007 British Columbia's Mountain Caribou Recovery Implementation Plan was announced. This collaboration between conservation organizations, First Nations, the forest industry, and outdoor recreation groups aims to restore the mountain caribou population to pre-1995 levels of more than 2,500 animals throughout their existing range.

BIODIVERSITY BC

In late 2004 a partnership of governments and nongovernmental organizations formed the BC Conservation Lands Forum. The mandate of the forum is to secure and improve the management of public and private lands to conserve biodiversity. An independent committee of the Forum was established to develop a provincial biodiversity strategy. Through an extensive consultation process with scientific experts on biodiversity, the committee, which is now called Biodiversity BC, produced a comprehensive report on the Status of Biodiversity in British Columbia in 2007. The report summarizes the current status of terrestrial and freshwater aquatic species and ecosystems in the province, their global significance, and gaps in current knowledge. Based on this and other reports, Biodiversity BC is developing a Biodiversity Action Plan Discussion Paper for release in late 2007. This will be the basis for consultation with stakeholders, including First Nations and the public, on options and priorities for conserving biodiversity in the province. The intent is to have a finalized 5-year action plan for biodiversity completed by the end of 2008 and to begin implementing that plan in 2009.

Organizations with representation on Biodiversity BC include land conservation groups: Ducks Unlimited Canada, The Land Conservancy of British Columbia, Nature Conservancy of Canada, The Nature Trust of British Columbia, Pacific Salmon Foundation, and the Canadian Parks and Wilderness Society (BC) representing other nongovernmental organizations; Habitat Conservation Trust Fund; the provincial government (Ministry of Agriculture and Lands and Ministry of Environment), the federal government (Environment Canada), and municipal governments (Union of British Columbia Municipalities). For more information and to follow the progress of the project e-mail *info@biodiversity.org*.

Other Initiatives

There are many other initiatives by international bodies, municipal governments, community groups, and volunteers. The following list includes only a few of them.

- The Greater Vancouver Regional District Biodiversity Strategy: This collaborative effort engages the public, land use planners, and decision-makers in conserving the ecosystem components, functions, and services that remain in the District—which is expected to have a population of nearly three million people by 2021. (*www.gvrd.bc.ca/growth/biodiversity.htm*)
- Nature Canada and Bird Studies Canada: These Canadian partners, with BirdLife International, designate Important Bird Areas (IBA) to protect and monitor a network of vital

habitats for the conservation of bird populations and biodiversity around the world. (*www.naturalists.bc.ca/projects/iba/iba_intro.htm*)

- Habitat Stewardship Program (HSP) for Species at Risk: This is a funding program to contribute to the recovery of species by engaging the public in conservation actions that benefit wildlife. The HSP provides funding stewardship projects that protect or conserve habitats for species designated by COSEWIC as endangered, threatened, or of special concern. The HSP is one of the three main federal funding programs implemented by Environment Canada, Fisheries and Oceans Canada, and the Parks Canada Agency. (*www.cws-scf.ec.gc.ca/hsp-pih/default.asp*)
- B.C. Trust for Public Lands: Established in 2004, the trust secures and manages ecologically sensitive lands, and plans for biodiversity conservation across the province. The Land Trust Alliance is delivered through the B.C. Conservation Lands Forum, a partnership between government and the conservation sector. (*www.landtrustalliance.bc.ca/*)

WHAT CAN YOU DO?

British Columbians make many personal choices that affect the natural environment and the species that live there. For example, choosing to consume fewer resources and produce less waste relieves some of the pressure on the native species and on ecosystems that are home to living organisms. The effect of this can be multiplied many times if everyone makes choices that reduce the pressure on the planet's ecosystems. Here are some other things you can do.

- Learn more about the animals and plants in British Columbia. Local natural history societies, as well as national and provincial parks, offer opportunities for learning about plants and animals in their natural environment. The Federation of B.C. Naturalists acts as the hub for a network of natural history societies in towns and cities across British Columbia. Find a local club at *www.naturalhistory.bc.ca/VNHS/index.htm*.
- Get involved! Join a local advisory board, wildlife enhancement group, or community planning team. Make sure protection of species at risk is on the agenda of your local community plan and regional or municipal governments. Participate in species at risk consultations. Support groups that are working on species at risk in British Columbia.
- Encourage backyard biodiversity by providing habitat for native animals and plants. Naturescape British Columbia is a program that helps people bring human communities closer to living in harmony with nature by providing information on how to restore, preserve, and enhance wildlife habitat in urban and rural landscapes and yards. Find out if you have species at risk on your land. Learn how to foster these species, and work with a local conservation group or recovery team. (*www.hctf.ca/nature.htm*)
- Participate in citizen science projects. You can enter bird sightings on the eBird website (*http://ebird.org/content/canada/*), participate in local butterfly counts, Christmas bird counts (*www.bsc-eoc.org/national/cbcmain.html*), BC Frogwatch (*www.env.gov.bc.ca/wld/frogwatch*), and surveys of breeding birds, plants, even worms (through Nature Canada *www.naturecanada.ca/*).

- Do not move alien species, such as fish, frogs, turtles, or problem wildlife to other areas. Work to reduce alien species in the environment and don't buy aggressive non-native plants for landscaping. If you have an alien plant species on your property that is seeding freely (such as ivy, Scotch broom, gorse) take responsibility for removing it.
- Be informed about sustainably harvested food from the wild, including fish, and buy accordingly. Buy from local outlets and farms that have species-friendly management.
- Keep pets from roaming free. Dogs, and especially cats, can kill or harass birds, snakes, and other wildlife in suburban and rural areas.
- Be responsible about recreation, including respecting closed areas and decommissioned roads.
- Consider protecting your land for the future with conservation covenants or agreements. See: Land Trust Alliance of B.C. (*www.landtrustalliance.bc.ca*)

Last, but not least: share your knowledge of, and passion for, biodiversity with friends, children, and co-workers. Project WILD provides wildlife-focussed conservation education for K–12 teachers and their students. (*www.projectwild.org/*)

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GLOSSARY

Alien species: A plant or animal that has been introduced by humans to a location outside its native range. Also called introduced, non-native, exotic, and invasive species.

Anadromous: Animals that must ascend rivers and streams from the sea in order to breed.

Aquaculture: The controlled cultivation and harvest of aquatic animals or plants, such as finfish (e.g., salmon), shellfish (e.g., clams, oysters), and edible seaweeds.

Aquifer: An underground layer of rock and sand that contains water and is the source of groundwater for wells and springs.

Baseline Thematic Mapping (BTM): A digital integration of satellite imagery and land-use, land-cover, and topographic data to produce an "image map" with contour lines and vector planimetry information.

Bioaccumulation: An increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things if they are taken up and stored faster than they are broken down or excreted.

Biodiversity: The variety and abundance of life, including ecosystems, communities, and the genetic composition of species. Also called biological diversity.

Biogeoclimatic Ecosystem Classification (BEC): A classification system in British Columbia that distinguishes terrestrial zones based on climate, soils, and dominant vegetation.

Biological controls: Using natural enemies of a particular species, usually predators and pathogens, to control population.

Biomagnification: The process that results in the accumulation of a chemical in an organism at higher levels than are found in its food. It occurs when a chemical becomes more and more concentrated as it moves up through a food chain.

Blue listed species: A species classified by the BC Conservation Data Centre as not immediately threatened but of concern because of characteristics that make it particularly sensitive to human activities or natural events.

Canada-wide Standards (CWS): Intergovernmental agreements that recommend levels or concentrations of substances in the surrounding environment and include targets and time frames for achieving the target. CWS have been developed for benzene, dioxans, furans, mercury, particulates, ground-level ozone, and petroleum hydrocarbons.

Capability: The inherent ability of the land to produce agricultural crops or wildlife habitat requirements.

Carcinogen: A substance that may cause cancer in animals or humans.

CCCMA: Canadian Centre for Climate Modelling and Analysis (located at the University of Victoria).

CDC (BC Conservation Data Centre): The provincial government office that tracks species and ecosystems that are in some danger of disappearing from British Columbia. The CDC annually publishes the provincial red and blue lists.

Certification (of products for sustainability): A process whereby an independent, third-party auditing body conducts an inspection and awards a certificate using independently developed standards and objectives.

CO_2 equivalent: The amount of CO_2 that would cause the same effect as a given amount or mixture of other greenhouse gases.

Congener: A term in chemistry that refers to one of many variants or configurations of a common chemical structure. Although similar, congeners may have different toxicological properties and fates in the environment.

Conservation covenant: A legal agreement that specifies the ways in which a piece of land can be used. A conservation covenant is incorporated into the land deed and protects the land in perpetuity.

Conservation: The protection of wild species and their ecosystems.

Conservation status: A designation defining the current level of risk for a particular species or ecosystem. It is an indicator of the likelihood of a species survival either in the present day or the near future.

Contamination: Substances, including those found naturally, that are present at concentrations above natural background levels, or whose distribution in the environment has been altered by human activity.

Corridor: An area of intact habitat that allows wildlife to move in relative safety from one place to another.

COSEWIC (Committee on the Status of Endangered Wildlife in Canada): A national committee of experts that assesses and designates which wild species are in some danger of disappearing from Canada.

Critically Endangered: IUCN classification for a species for which the best available evidence shows that it is facing an extremely high risk of extinction in the wild.

Dioxins and furans: Two families of chlorinated organic compounds that can be formed as by-products of activities such as pulp bleaching and waste incineration. Both can persist in the environment for many years and some forms are highly toxic.

Disturbed environment: Alteration of part or all of a living community from natural or human activity. Storms, landslides and El Niños are examples of natural events; clearcutting, pollution, and harbour dredging are examples of human-caused disturbance.

Ecologically intact: An area that has no roads, railways, or seismic lines and the habitats are not fragmented by human use.

Ecoregion Classification: A classification system in BC that describes areas of the province with similar climate, physical land and water features, vegetation, and wildlife potential. The classification has five levels from broadest to narrowest: ecodomain, ecodivision, ecoprovince, ecoregion, and ecosection. See Demarchi 1996 for more details. See also, Marine Ecosystem Classification.

Ecosection: The finest scale in the Ecoregion Classification system. Forty ecosections make up the coastal and marine region of BC.

Ecosystem: Plants, animals, and the physical environment (water, air, soil, etc.) interacting in a given area.

Ecotourism: Nature-based tourism that is ecologically sustainable.

Ecotype: A subgroup within a species that has developed distinct physical or behavioural characteristics in response to its local environment that persist even if individuals are moved to a different environment.

Endangered: A species facing imminent extirpation or extinction very soon (COSEWIC).

Endemic: A species native to, and restricted to, a particular geographical region.

Endocrine: System of the body that releases hormones into the blood stream or lymph system. These hormones control growth, metabolism, mood, and reproduction and influence almost every cell and organ in the human body.

ENSO: El Niño Southern Oscillation, an interannual variation in climate related to large-scale shifts in tropical atmospheric pressure manifested by El Niño and La Niña events.

Estuary: The mouth of a river where fresh and salt water meet and mix. Estuaries tend to be highly productive environments.

Eutrophication: A process by which over-enrichment of a water body with nutrients results in excessive plant growth and oxygen depletion.

Exotic species: See Alien species.

External threat (to protected areas): Something occurring outside the protected area boundary that threatens ecosystems and biodiversity within the protected area. For example, roads, urban development, tourist infrastructure, forestry, mining, agriculture.

Extinct: A species that no longer exists.

Extirpated: A species no longer existing in the wild locally, but occurring elsewhere.

Fecal coliform bacteria: Bacteria found in the intestinal tracts and feces of warm-blooded animals.

Fish population: A discrete group of fish that are of the same species and, in the case of salmon, spawn in the same stream.

Fish stock: A species, subspecies, geographical grouping, or other grouping of fish that is managed as a unit.

Flux: The amount of a substance, such as mercury, flowing from or over a given area per unit time.

Food chain/food web: The feeding relationships between species in a biotic community, from the producers (plants) up through various levels of consumers (animals). An example would be algae eaten by the water flea, which is eaten by a minnow, which is eaten by a trout, which is finally eaten by an eagle (or a person). Although often portrayed as a single chain of events, the reality is a web of interactions between species.

Fossil fuel: Any carbon-containing fuel derived from the decomposed remains of prehistoric plants and animals, e.g., coal, peat, petroleum, and natural gas.

Fragmentation: Changing a continuous ecosystem, such as a forest, into smaller patches by disturbing the land. Fragmentation can be caused naturally, for example by fire, landslides, and trees falling in storms, and by humans during road building, forest harvesting, land clearing, and other activities.

Furans: See Dioxins and furans.

Greenhouse gases: A gas that absorbs and re-emits infrared radiation, warming the earth's surface and contributing to climate change. Greenhouse gases are released into the atmosphere by many naturally occurring processes and by human activities such as fossil fuel combustion, deforestation, agriculture, and industrial activity.

Gross domestic product (GDP): The total market value of all goods and services produced within a country during a specified period of time.

Groundwater: Water beneath the earth's surface held in saturated soil and rock. Groundwater is a major source of water for agricultural and industrial purposes. It supplies wells and springs and is an important source of drinking water.

Habitat: The place where a plant grows or an animal lives, and all the characteristics of that place, including climate, food, shelter, and others.

Halogenated compound: An organic compound that has one or more halogens, such as fluorine, chlorine, or bromine, substituted for hydrogen molecules. In a fully halogenated compound, all hydrogen has been replaced with chlorine or fluorine. The resulting compounds are generally less flammable but more toxic.

Hydrograph: An instrument that records a specific hydrologic measurement over time, such as water level, discharge, or velocity.

Impervious surface: A hard surface that prevents or slows the entry of rain and meltwater into the soil, causing water to run off the surface in greater quantities and at an increased rate of flow. Examples include roads, rooftops, and parking lots.

Internal threat (to protected areas): Something occurring inside the protected area boundary that threatens ecosystems and biodiversity within the protected area. For example, roads, visitor facilities, recreational use, exotic species, and activities that consume or extract resources.

Intertidal: The portion of seashore between the highest and lowest tides.

Introduced species: See alien species.

IPCC: Intergovernmental Panel on Climate Change: An international group of experts responsible for scientific assessments of global change.

Isostatic rebound: A geological process in which the earth's surface rises as stresses imposed by the weight of ice during the last glacial period are gradually released.

IUCN (World Conservation Union): The world's largest conservation network composed of 82 states, 111 government agencies, more than 800 nongovernmental organizations (NGOs), and some 10,000 scientists and experts from 181 countries in a unique worldwide partnership. The IUCN publishes the IUCN Red List of Threatened species, a global list of species at risk.

Landsat: Land Remote-sensing Satellite. A series of satellites that produce images of the earth from space.

Marine Ecosystem Classification: A part of the BC Ecoregion Classification system that further divides the benthic marine environment into 1201 ecounits based on seven physical parameters. There are 263 unique ecounit codes along the BC coast.

Marine protected area: A generic term used to describe an area of intertidal or subtidal terrain, together with its overlying or contiguous water and its associated flora and fauna, and historical and cultural features, which has been reserved by law to protect all or part of the habitats and/or species found within it. Note: The Canadian government also has specific, legislated designations called Marine Protected Areas. These provide a certain level of protection to an area.

MDF: Maximum Daily Flow, the highest recorded daily average discharge at a river gauging station (in cubic metres per second).

Nearshore: An indefinite zone extending seaward from the shoreline to well beyond the breaker zone.

Observation wells: A network of unused dug and drilled wells covering major groundwater areas of the province that monitor water quality data and water level fluctuations on a continuous basis. There are 158 active (as of Sept 2006) observation wells in British Columbia.

Offshore: The zone beyond the nearshore zone where sediment motion induced by waves alone effectively ceases and where the influence of the sea bed on wave action is small in comparison with the effect of wind.

Orthophotograph: A photograph on which all distortions caused by tilt, relief, and perspective have been corrected.

Ozone: A compound consisting of three oxygen atoms. It is a poisonous gas formed through chemical reactions in the atmosphere involving volatile organic compounds, nitrogen oxides, and sunlight. Ground-level ozone, a primary constituent of smog, is produced by the combination of pollutants from many sources, including smokestacks, cars, paints, and solvents, in the presence of heat and sunlight.

Particulate matter: Microscopic solid particles or liquid droplets suspended or carried in the air (e.g., soot, dust, fumes). Particles with a diameter of 10 micrometres or less are referred to as PM_{10}, particles smaller than 2.5 micrometres are referred to as $PM_{2.5}$.

Pathogen: A disease-causing agent, including bacteria, viruses, and fungi, usually microscopic in size.

PDO: Pacific Decadal Oscillation, a decadal-scale climate phenomenon related to changes in the geographic location of a persistent low-pressure centre over the Gulf of Alaska.

Pelagic: Organisms that live in open waters away from the bottom of aquatic ecosystems such as lakes, rivers, and the ocean.

Persistent Organic Pollutants (POPs): Chemicals that remain intact in the environment for long periods, become widely distributed geographically, accumulate in the fatty tissue of living organisms, and are toxic to humans and wildlife.

PBDE: Polybrominated diphenyl ether is a chemical widely used as a flame retardant in clothes, cushions, and some plastic items. PBDEs are potentially toxic to humans.

Phylum: A major subdivision of classification in the animal kingdom.

Phytoplankton: Microscopic floating plants that live suspended in bodies of water and drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current.

Pollutant: A contaminant whose concentration in the environment is high enough to result in deleterious effects.

Polygon: As used in computerized mapping (Geographical Information Systems), a stream of digitized points approximating the delineation (perimeter) of an area on a map. It is used to graphically represent the features of a defined area (e.g., an ecosystem or a type of land use) along with its associated attributes.

Protected area: A generic term used to describe areas of land and/or water that are protected in some way. The protected area may be called a park, an ecological reserve, or another name. The Canadian government also has specific, legislated designations called Protected Areas and Marine Protected Areas. These provide a certain level of protection to an area.

Protected unit: An area of protected land or protected ocean that is geographically continuous. For example, two protected areas that join one another make up one unit, and a protected area that occurs in four geographically distinct fragments makes up four units.

Receiving environment: The site or area where pollution or wastewater ends up after being discharged from a treatment facility or an outfall; usually a stream, river or ocean environment.

Recruitment: The number of individuals entering a population or a fishery each year.

Red listed species: A species that is legally designated as threatened or endangered under the provincial Wildlife Act, is extirpated, or is a candidates for such designation.

Regeneration: The replacement or renewal of a forest stand by natural or artificial means.

Riparian: Beside or along the bank of a stream or river.

SARA (Species At Risk Act): A federal act, proclaimed in June 2003, that applies to all federal lands in Canada, all wildlife species listed as being at risk, and their critical habitat.

Sensitive ecosystems: Ecosystems that are particularly vulnerable to human or natural impacts.

Smart growth: Environmentally sensitive land development with the goals of minimizing dependence on auto transportation, reducing air pollution, and making infrastructure investments more efficient.

Snow water equivalent: The amount of liquid water contained in a volume of snow, i.e., the amount of water measured from melting a known amount of snow.

Special Concern: A species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats (COSEWIC).

Species at risk: A wild species that is at risk of extinction or extirpation. The level of risk is identified, from highest to lowest, as endangered, threatened, and special concern. Both federal and provincial agencies designate species at risk, but only federal listings have legal protection under the Species at Risk Act (SARA).

Species: The classification for a group of organisms that is distinct from other such groups. Breeding within the group will produce fertile offspring.

SPSS: Statistical Package for the Social Sciences, a set of software utilities available from SPSS Inc.

Stewardship: Looking after something important and valuable that you do not own.

Stock: See Fish stock.

Subspecies: A formally named subdivision of species composed of geographically discrete populations that differ in appearance, behaviour, and/or genetics from other members of the species. Subspecies are capable of interbreeding with other members of their species.

Subtidal: The area extending below the lowest tidemark.

Taxon (pl: taxa): A group into which similar organisms are classified. For example, genus, species, or subspecies.

Taxonomy: Theory and practice of classifying living organisms.

TEQ: Toxicity equivalence, the international method of relating the toxicity of various dioxin/furan congeners to the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin.

Teratogen: An agent or substance that may cause physical defects in the developing embryo or fetus when a pregnant female is exposed to that substance.

Terrestrial protected area: A generic term used to describe areas of land (including freshwater) that are protected in some way. The protected area may be called a park, an ecological reserve, or another name. The Canadian government also has specific, legislated designations called Protected Areas. These provide a certain level of protection to an area.

Threatened: A species likely to become endangered if limiting factors are not reversed (COSEWIC).

Terrain Resource Information Management Program (TRIM): A program to produce digital maps using the Universal Transverse Mercator coordinate system as the cartographic framework. TRIM mapping for BC consists of 7027 mapsheets covering the province at a scale of 1:20,000. Each mapsheet is precisely 12 minutes of longitude wide by 6 minutes of latitude high.

Total suspended solids (TSS): A measurement of the amount of solid matter in wastewater or effluent, usually expressed in parts per million.

Trophic: Pertaining to food or nutrition.

Trophic level (TL): The feeding position occupied by a certain organism in a food chain. Plants have a TL value of 1, herbivores (plant-eaters) have a TL of 2, and so on up the food chain. The value for top predators rarely exceeds 5.

Upland: Any land that occurs above the high tide mark at the seashore.

Urban sprawl: A pattern and pace of land development in which the rate of land consumed for urban or suburban purposes exceeds the rate of population growth using the developed land. Sprawl results in an inefficient and consumptive use of land and its associated resources.

Variety: Taxonomic classification, used primarily in plants, to indicate any kind of variation within a species.

Volatile organic compounds (VOCs): Carbon-containing compounds that evaporate into the air; they often have an odour and contribute to the formation of smog. Some examples include gasoline, alcohol, and the solvents used in paints.

Vulnerable: IUCN classification for species for which the best available evidence shows that it is facing a high risk of extinction in the wild.

Water Quality Index (WQI): An index developed by the Canadian Council of Environment Ministers that summarizes large amounts of water quality data (e.g., acidity, fecal coliforms, dissolved oxygen). The results are combined to provide a water quality ranking (good, average, poor) for individual waterbodies and indicate a potential threat to various uses of water (e.g., aquatic habitat, irrigation, recreation, and drinking water supplies).

Yellow List: Uncommon, common, declining, and increasing species—all species not included on the provincial Red or Blue lists, but tracked by BC Conservation Data Centre.

Environmental Trends
in British Columbia: 2007

This is the fourth in a series of Environmental Trends reports from the Ministry of Environment. This year's report contains 44 indicators and over 25 supplementary measures. It includes indicators showing pressures on the environment and indicators that show the impact of measures intended to respond to problems.

This edition of Environmental Trends updates previously reported indicators. It also introduces indicators developed since the last report to improve our understanding of environmental conditions.

The data for the indicators came from a variety of sources, but mainly provincial or federal monitoring programs and from research projects.

More than 80 people from provincial and federal ministries and other organizations were involved in this project. They provided data, checked the accuracy of the analyses and reviewed the papers.

Visit the Environmental Trends in B.C. web site to find out more:

www.env.gov.bc.ca/soe/et07